Sustainable warehousing

An empirical research at Unilever on building options and collaboration models in sustainable warehousing

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Management summary

Inducement

Unilever uses logistic service providers for its distribution activities, to get the products from the sourcing units, via warehouses to its customers. For the *home and personal care* warehouse in Raamsdonksveer the current contract is expiring. Since the current capacity of Raamsdonksveer is not sufficient anymore, Kuehne + Nagel (a logistic service provider) will build a new multi-user warehouse. From the Unilever vision it can be derived that this new warehouse has to be sustainable. The first research goal for this thesis is therefore:

- *Find possible options to ensure a warehouse where sustainability meets performance.*

Approach

To achieve this research goal, options are gathered to make this warehouse more sustainable. The gathered options are aiming to reduce the required energy, warmth, water and light for the warehouse and minimize waste production. These sustainability options are reviewed by means of a multi-criteria analysis. The criteria used are *little negative impact on the operation, improvement of the working environment*, *low effort for implementation*, *low costs*, *increase ecological sustainability*, *increase marketable image* and *increase BREEAM score*. BREEAM is the world's most widely used method of assessing, rating and certifying the sustainability of buildings. The new Kuehne + Nagel warehouse will also be assessed by means of this method and the aim is to get a certificate with the score 'Good'.

This multi-criteria analysis gives a first distinction between options that are recommended and options that are discommended. There are also sustainability options where more technical research is needed. This research is done in co-operation with the real estate service provider CBRE. The research points out that a wind turbine and PV-panels are interesting options to consider. For these interesting options applies that high investment is needed and inter-firm collaboration is desirable because of the smaller investment per party and shared risk, also the expertise of multiple parties can be used. Therefore the second research goal is:

- *Give insight in forms of collaboration between parties in a complex and multi-user project to realize sustainability.*

To get more insight in inter-firm collaboration and specifically in inter-firm project investment, literature review as well as practical research is performed. For inter-firm collaboration two types of collaboration are reviewed that have a link with both logistics and sustainability. These inter-firm networks are *eco-industrial parks* and *freight villages*. An eco-industrial park is an industrial park in which businesses cooperate in an attempt to reduce waste and pollution, efficiently share resources and help achieve sustainable development. A freight village is a localized cluster of transport and logistics facilities which are co-located and coordinated for synergies. For inter-firm project investment literature about project finance is evaluated and two examples from practice are studied.

Results

Sustainability options: the result from the multi-criteria analysis is a list of more than 20 recommended options, these options are shown in the table below. These recommended sustainability options, like dynamic lighting with motion sensors, if applied, will reduce the energy demand by almost 50%. This reduction is compared to a warehouse that complies with the minimum standard of Dutch building regulations. To satisfy the remaining energy demand in a sustainable way a wind turbine and PV-panels, realized by the multiple users of the warehouse, are suggested.

Heating	**Lighting**
Insulation (Rc 3.5)	Determination of required light levels
Thermographic assessment (inside out)	Determining most effective location of light sources
Thermographic assessment (outside in)	Windows (east and west side)
Air curtains for loading docks	Intelligent lighting/motion sensors
Humidity control	Fluorescent T5 lighting (high frequency and dynamic)
Heat recovery from ventilation	
Acoustic alarm for warehouse doors	**Water**
Green façade	Motion sensors for taps and showers
Radiation heating + fans	Double flush systems and flush disruptors for toilets
Waste	**Energy**
Stimulating waste segregation	Power consumption (sub)meters
Compressing/cracking of waste	Wind turbine
Origin of building material	PV-panels

Recommended sustainability options for the new Kuehne + Nagel warehouse

Inter-firm collaboration: to make an inter-firm collaboration a success, some factors should be taken into account. All parties involved should benefit in a direct or indirect way. A condition to achieve this benefit is a willingness to invest time and/or money. Stakeholders should be involved and managed. One of the important stakeholders in projects like the sustainable energy for the new Kuehne + Nagel warehouse is the government or public authority because of their influence on permits, funding, environmental law and possible investments. Creating synergy and moderate conflicting interests can best be done by an autonomous organizational structure.

Inter-firm project investment: a specific form of inter-firm collaboration is inter-firm project investment. In the literature and case studies we found that there are a lot of possibilities for financing a project. The sources used elaborate on the fact that a special purpose company (SPC), comparable to the autonomous organizational structure from inter-firm collaboration, is needed. A SPC gives the possibility to finance a project by multiple parties. This SPC can also realize non or limited recourse to the sponsors of the project. Furthermore it became clear that the organizational structure and the capital structure of a project are important but exist in many forms. The most suitable form should be discussed by sponsors and lenders involved.

Recommendations

For the sustainability options that minimize the use of natural resources and do not need project finance it is recommended to include them in the building requirements for the developer. These options will decrease the energy demand of the warehouse.

The remaining energy can be supplied in a sustainable way by PV-panels and a wind turbine. It is recommended that project finance is used to realize these two sustainability options. This under the condition that the benefits of the project exceed the costs to form and maintain this type of financial structure. One of the big advantages is the fact that sponsors are only liable for their invested money (non recourse) if a special purpose company is used. In addition a high return on investment can be realized if equity is 20%-40% of the total investment. To raise debt for those projects pledges or guarantees can be used to persuade lenders. The organizational structure depends on the capital structure chosen and should be discussed by the project sponsors, lead bank and other lenders.

Besides these recommendations it is advised to use the sustainability options as a part of the marketing for a sustainable supply chain. As this research focused on the construction phase of the warehouse, further research is advised on sustainability during usage, maintenance and transport.

Samenvatting

Aanleiding

Unilever maakt gebruik van logistiek dienstverleners zoals Kuehne + Nagel, waaraan delen van het logistieke proces worden uitbesteed zoals het opslaan en transporteren van haar goederen naar de klanten. Het huidige contract van Unilever bij het distributiecentrum van Kuehne + Nagel (K+N) in Raamsdonksveer loopt af. In dit distributiecentrum worden Unilever producten voor het huishouden en persoonlijke verzorging opgeslagen. Aangezien dit distributiecentrum onvoldoende capaciteit heeft en geen uitbreidingsmogelijkheden kent heeft K+N aangekondigd een nieuw distributie centrum te laten bouwen waar meerdere verladers zullen worden bediend. De visie van zowel Unilever als K+N is gericht op het verduurzamen van hun (logistieke) bedrijfsprocessen. Het eerste doel van dit onderzoek is daarom:

- Het vinden van mogelijkheden om een distributiecentrum te bouwen waar duurzaamheid en prestatie samenkomen

Aanpak

Om dit doel te bereiken zijn meerdere stappen doorlopen in dit onderzoek. Allereerst zijn er mogelijke duurzame opties verzameld en getoetst. De verzamelde opties zijn erop gericht om de benodigde energie, water, warmte en licht te reduceren en het afval gebruik tot een minimum te beperken. De toetsing van deze opties is gedaan door middel van een multi-criteria analyse waarbij onder andere op duurzaamheid, kosten, impact op de operatie en verbetering van de werkomgeving is beoordeeld.

Door deze multi-criteria analyse kwam een eerste scheiding naar voren tussen opties waarvan implementatie aanbevolen wordt en opties die afgeraden worden. Het afraden van de opties heeft te maken met bijvoorbeeld de afname in energiegebruik die niet opwoog tegen de kosten voor de implementatie van deze optie. Ook was er nog een aantal opties waar eerst meer (technisch) onderzoek naar moest worden gedaan alvorens een gefundeerd advies kon worden gegeven. Dit onderzoek is in samenwerking gedaan met een adviesbureau (CBRE). Dit onderzoek wijst erop dat een windmolen en PV-panelen interessante opties zijn. Voor deze interessante opties geldt dat er grote investeringen nodig zijn en dat samenwerking tussen partijen in het distributiecentrum gewenst is om deze opties te realiseren. Door een samenwerking tussen partijen kan er een kleiner bedrag per partij worden gerealiseerd. Ook kunnen de risico's worden gedeeld en expertise van meerdere partijen worden gedeeld. Om deze reden is het tweede onderzoeksdoel:

- Het geven van inzicht in vormen van samenwerken voor een complex project waar meerdere partijen bij betrokken zijn en waar duurzaamheid wordt gerealiseerd

Om meer inzicht te krijgen in samenwerking tussen bedrijven is een literatuur studie gedaan. Deze studie was gefocust op samenwerkingsvormen die gericht zijn op duurzaamheid en logistiek. De twee vormen die wij hebben bestudeerd zijn *eco-industrial parks* en *freight villages*. Een eco-industrial park is een industrie terrein waar bedrijven samenwerken om een reductie in afval en uitstoot te bewerkstelligen, grond-, en hulpstoffen efficiënt te delen en duurzame ontwikkeling te stimuleren. Een freight village is een cluster van transport en logistieke faciliteiten die zijn samengebracht en waar

samen wordt gewerkt om synergieën te bereiken. Zo worden vrachten gebundeld en is het mogelijk om via water te vervoeren door een grote stroom aan goederen te creëren.

Daarnaast is er ook onderzoek gedaan naar project financiering. Dit is een specifieke vorm van samenwerken die nodig is om bijvoorbeeld een windmolen of pv-panelen te realiseren. Deze twee literatuur studie worden ondersteund met een aantal praktijk voorbeelden waarbij meerder partijen samen investeren in duurzaamheid.

Resultaten

Duurzame opties: de aanbevolen duurzame opties die als resultaat uit de multi-criteria analyse kwamen zullen, als ze worden ingevoerd, de vraag naar energie met bijna 50% reduceren. Een voorbeeld van een duurzame oplossing is bijvoorbeeld dynamische verlichting met bewegingssensoren. De reductie van bijna 50% is in vergelijking met een distributiecentrum dat voldoet aan de minimum eisen van het Nederlandse bouwbesluit. Om de overgebleven energiebehoefte op een duurzame manier op te wekken worden een windmolen en pv-panelen, gerealiseerd door meerdere partijen uit het distributiecentrum, aanbevolen.

Samenwerking tussen bedrijven: om een samenwerking een succes te laten worden zijn er een aantal factoren van belang. Zo zullen alle deelnemende partijen op een directe of indirecte manier moeten profiteren van de samenwerking. Om te kunnen profiteren zullen partijen bereid moeten zijn tot het investeren van tijd en/of geld. Alle betrokken partijen, zoals de sponsoren en investeerders maar ook werknemers, zullen betrokken moeten worden. Een andere zeer belangrijke betrokken partij is de overheid/publieke autoriteit vanwege hun invloed op vergunningen, subsidies, regelgeving en mogelijke investeringen in de duurzame projecten. Om tot synergie te komen en onenigheid in conflicterende belangen op te lossen kan er het beste gebruik worden gemaakt van een autonome organisatie structuur.

Gezamenlijk investeringsproject: een specifieke vorm van samenwerking tussen bedrijven is het samen investeren in projecten. In de literatuur en praktijk voorbeelden hebben wij ontdekt dat er veel mogelijkheden zijn voor projectfinanciering. De meeste van de gebruikte bronnen gaan in op het gebruik van een zogenoemde special purpose company (SPC, voor een speciaal doel opgerichte entiteit). Deze SPC is vergelijkbaar met de autonome organisatie structuur die wij gevonden hebben in de literatuur over samenwerking tussen bedrijven. Een SPC biedt de mogelijkheid om met meerdere partijen een investering te doen, in bijvoorbeeld een project. Door gebruik te maken van een SPC zijn sponsoren in het project alleen aansprakelijk voor het geïnvesteerde bedrag, dus niet voor de rest van hun bezittingen. Verder is het ons tijdens deze studie duidelijk geworden dat de organisatie en kapitaal structuur belangrijk zijn maar in vele gedaantes voorkomen. De best passende vorm moet worden bepaald door de betrokken sponsoren en investerende partijen, waarbij de organisatiestructuur de kapitaal structuur volgt.

Aanbevelingen

Er wordt aanbevolen om project financiering te gebruiken om PV-panelen en een windturbine te realiseren als de opbrengsten hoger zijn dan de kosten om deze vorm van financiering op te zetten. Een

groot voordeel van project financiering is dat sponsors van het project alleen aansprakelijk zijn voor hun ingelegde geld en niet voor overige bezittingen als er gebruik wordt gemaakt van een autonome bedrijfsvorm. Daarnaast kan een hoger rendement worden gehaald op het geïnvesteerde bedrag als het eigen vermogen 20-40% van de totale investering beslaat. Om vreemd vermogen te verwerven kan er door de sponsoren een garantie van bijvoorbeeld afname worden afgegeven of er kan een onderpand worden verleend voor de leningen. De organisatiestructuur voor de projecten volgt de financiële constructie en zal in overleg tussen sponsors en verschaffers van vreemd vermogen moeten worden vastgesteld.

De aanbevolen duurzame opties die geen vorm van project financiering behoeven moeten worden opgenomen in het programma van eisen. Op deze manier kan de projectontwikkelaar die het gebouw neerzet worden aangespoord tot het realiseren van deze mogelijkheden.

Naast deze aanbevelingen is het ook mogelijk om de genoemde opties te gebruiken als deel van de marketing van een duurzame supply chain waar duurzaamheid en prestatie samenkomen. Naast de constructiefase, waar dit onderzoek op is gericht, zijn ook het gebruik, het onderhoud en het transport mogelijke gebieden van verder onderzoek naar verduurzaming.

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Glossary

ADR: alternative dispute resolution. This resolution sets requirements for the storage of dangerous goods. With these specifications our search for sustainability options started.

BREAAM-NL: building research establishment environmental assessment method (Dutch version). A method of assessing, rating and certifying the sustainability of buildings.

3 Cs: cost, carbon and customer service. These are the three important pillars in Unilever supply chain project management.

DC: distribution center. Another word for warehouse, which is a place to store products, pick orders and prepared them for transportation, in some cases there are also repack activities.

EIP: eco-industrial park. This is an industrial park in which businesses cooperate with each other and with the local community in an attempt to reduce waste and pollution, efficiently share resources and help achieve sustainable development, with the intention of increasing economic gains and improving environmental quality.

FV: freight village. A localized cluster of transport and logistics facilities which are co-located and coordinated for synergies. The management of the shared facilities, equipment and services is centralized and among those facilities is an intermodal terminal.

HPC: home and personal care. This is the class of Unilever products that contains detergents, dishwashing tablets, deodorant, shampoo, toothpaste etc.

K+N: Kuehne + Nagel. The logistic service provider that will run the new warehouse.

MSO: marketing and sales organization. The organization that is responsible for the marketing of national products and representation of European brands into the local market of a country or country group (e.g., Benelux). The MSOs are also responsible for transport from the distribution centers to the customers.

PV-panels: photovoltaic panels. A system that is able to convert sunlight into electricity.

SPC: special purpose company. A legal entity created to fulfill a specific or temporary objective. This form of entity is used in project finance to isolate financial risk and enable inter-firm collaboration and investment.

SU: sourcing unit. The Unilever designation for their factories.

USCC: Unilever supply chain company. This company within Unilever controls the European supply chain and has decision taking authority. The USCC aims to create ‘one Unilever’ through identifying synergies and cooperation in the supply chain, aiming at generating cost savings.

USLP: Unilever sustainable living plan. A plan made by Unilever that set out a ten year journey towards sustainable growth of the company.

WDP: Warehouse De Pauw. WDP is a European leader in the development and leasing of logistics and semi-industrial property. This party is the developer of the new Kuehne + Nagel warehouse.

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1 Introduction

This thesis describes a master research for the University of Twente in the field of industrial engineering and management. This research was conducted at Unilever, one of the world's leading manufacturers of foods and home & personal care products. Unilever's products are used more than 2 billion times a day by consumers around the globe. Unilever is a company that originates from a merger between the Lever brothers, who where British soap makers and Margarine Unie, a margarine producer from the Netherlands. In the 1930 those two companies merged based on their common raw material (palm oil) and similar type of products. Since then Unilever grew via innovation, market growth and acquisitions. In 2012 Unilever reached the milestone of 50 billion Euros yearly turnover, thanks to its 171.000 employees and more than 400 well known brands worldwide (Unilever, 2013).

Unilever sells its products in 190 countries and is therefore organized into eight market clusters. This study focuses on the Unilever supply chain company (USCC) and the marketing and sales organisation (MSO) Benelux which is part of the European market cluster. MSO Benelux is responsible for the marketing and sales of Unilever for the consumer markets in the Netherlands, Belgium and Luxembourg. These consumers are reached via supermarkets like Albert Heijn and Jumbo, but also via other channels like beach clubs for Ola ice cream and drugstores for home and personal care products. The USCC has besides other tasks the responsibility for the factories/sourcing units (SUs), primary transport and warehouses. Figure 1 gives a simplified representation of the Unilever supply chain. The USCC is responsible for the product from supplier, via the SU, into the warehouse/distribution centre (DC). From the moment that the product leaves the DC till it reaches the customer the MSO is accountable. This is purely contract technical, in all processes there is a lot of overlap and mutual communication.

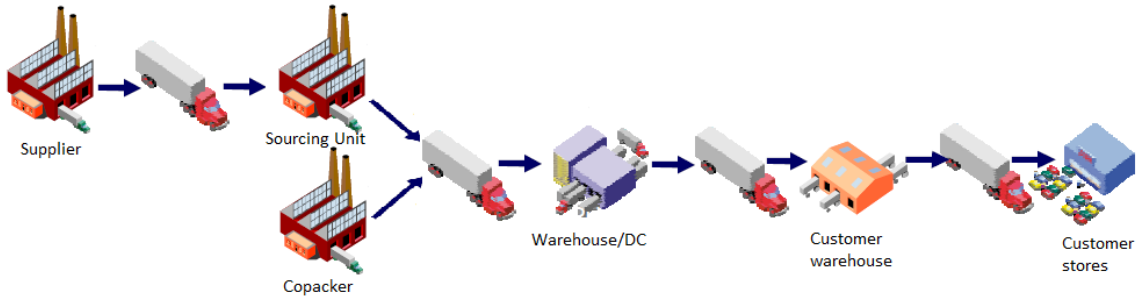


Figure 1 Unilever Supply Chain (simplified representation)

Products meant for MSO Benelux, which are coming from SUs and Copackers around the world, are brought to 5 DCs. Each of these DCs is responsible for one or more of the following product categories: home care, personal care, foods and refreshment. The foods products for the Netherlands are brought to Veghel, Home & personal care (HPC) for the Netherlands to Raamsdonksveer, Ice Cream and Chilled for the Benelux market resp. to Bergen op Zoom and Zeewolde, and Foods and HPC for the Belgium market to Bornem. These warehouses are not Unilever owned but storage space is hired in combination with transportation services from different logistic service providers (LSP). In these warehouses products are stored, orders are picked and prepared for transportation, in some cases there are also repack activities.

For the warehouse in Raamsdonksveer, where HPC products are stored, the current contract is expiring. Since the current capacity of Raamsdonksveer is not sufficient anymore, Unilever started a network study. As result of the study Unilever decided to continue the co-operation with Kuehne + Nagel (K+N), a globally represented logistic service provider that is also responsible for the current HPC warehouse in Raamsdonksveer and the foods warehouse in Veghel. To fulfil the space requirements of Unilever, K+N will build a new warehouse in Tiel. The location of the new warehouse is shown in Figure 2. To build such a new warehouse an intensive collaboration between Unilever and K+N is required. This collaboration is required for example to decide the size of the warehouse, the location, the design of the IT systems and the transition process to the new warehouse. All these activities are brought together into one project with the project name Madagascar. There is no specific reason for this name Madagascar but it makes the project recognizable and simplifies the communication about the new warehouse in Tiel. The project is led by two project managers, one from Unilever and one from Kuehne + Nagel. There are separate work streams that are specialized in specific areas, for example the work stream 'Environment & Sustainability' which is the work stream central in this study.

Figure 2 Location of the new Kuehne + Nagel warehouse Medel, Tiel (Kuehne + Nagel, 2013)

In November 2010 Unilever launched a long term strategy to be able to decouple growth from their environmental footprint, while at the same time increasing their positive social impact. The blue print of this strategy is the Unilever Sustainable Living Plan (USLP). One outcome of the strategy should be to halve the environmental footprint of Unilever products by 2020. In order to realise this outcome carbon emission has been included as one of the evaluation criteria used in all projects and processes next to cost and customer service (the 3 Cs). A sub-target for Unilever's global logistics is to keep CO2 emissions from Unilever's transport network including warehouses on the 2010 level or below. This sub-target should be realized whilst handling significantly higher shipment volumes resulting in a CO2 efficiency improvement of 40%. Therefore, amongst others, improved energy efficiency in the warehouses should be realized. Around 40% of the overall carbon emission in Europe is caused by energy used in buildings, which leads within logistics to increased attention on energy-efficient warehouses. As energy may count

for up to 10 % of total warehouse operation costs, energy savings reduce the costs significantly as well (Unilever, 2012).

Despite the fact that the new warehouse will not be Unilever owned, Unilever requires the warehouse to be sustainable. As defined by the Brundtland definition sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Three of the pillars of sustainability are environment, society and economy (Glavic & Lukman, 2007). These three pillars are all covered in this thesis; sustainability options are generated based on one of the pillars and tested against all three of them. With the USLP Unilever brought together those three pillars into one strategy. The USLP tries to look beyond company borders and wants to measure the effect in the complete supply chain. Therefore Unilever takes also the carbon emission of third party warehouses into account. But not only carbon emission is important for Unilever, also safety, improved health and well being for warehouse employees as well as positive external exposure play an important role. For this reason Unilever wants to have a better understanding on how a warehouse could be as sustainable as possible, while taking costs into account.

The new to build warehouse in Tiel should be a warehouse where ‘sustainability meets performance’. There are a lot of possibilities to make a warehouse more sustainable. In this report a lot of possibilities are listed and evaluated on multiple criteria. This will result in a list of recommended options to make the new Kuehne + Nagel warehouse more sustainable. Some of these possibilities do not require large investments and are easy to implement such as insulation of the building. Other options will need a more extensive investigation since investment costs are high and therefore have a long payback period. Those options have also another difficulty, namely the fact that the warehouse will be owned by an investor, hired by Kuehne + Nagel and used for products of multiple companies such as Unilever (shown schematically in Figure 3. In this construction a variety of contracts are signed between participating parties. To make the warehouse as sustainable as possible horizontal and vertical collaboration is needed. The different options how to collaborate in this situation are evaluated and recommendations will be given for the most suitable form of collaboration. An example of an option that will need a more detailed technical analysis and a suitable form of collaboration is a wind turbine.

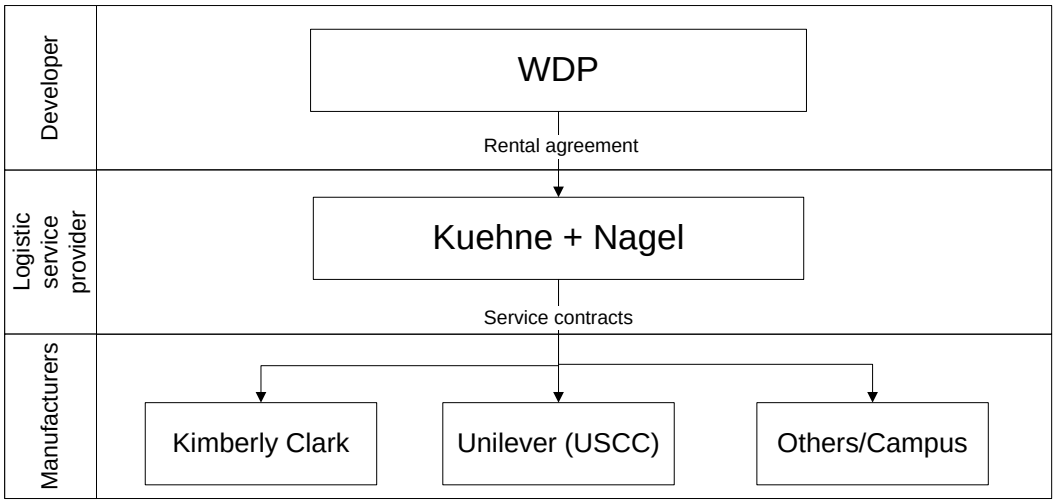


Figure 3 Contractual design of the new Kuehne + Nagel warehouse

2 Research design

This chapter first clarifies the motivation of this research that was already mentioned briefly in the introduction. Continuing, Section 2.2 and 2.3 elaborate on the research goal, research question and related sub questions. Section 2.4, 2.5 and 2.6 give a brief explanation of successively the methodology, scope and the outline of this research.

2.1 Research motivation

Currently the HPC products of Unilever are stored in a K+N warehouse in Raamsdonksveer. The growth ambition of Unilever causes the fact that more products go through the supply chain every day. Together with the fact that at the current location expanding is not an option, there is reason enough to have a new warehouse build and transpose completely to this new warehouse. The reason why it has to be a sustainable warehouse will be explained in the sequel of this section.

The world faces unprecedented challenges, amongst others a growing population that already passed 7 billion people. Together with a climate change, this leads to scarcity of water and food. According to the WWF we are consuming natural resources at a faster rate than the planet's capacity to replenish them. WWF calculated that is we all consume at the rate of Europe we would need three planets. Those challenges were the reason for the Kyoto protocol and discussion within the European Union for emission rights.

With product presence in over 190 countries, Unilever is confronted daily by water scarcity and the impact of a changing climate on their supplying farmers. Unilever takes its responsibility as producer to influence the complete supply chain with their end to end approach (from agriculture to sustainable product use and disposal). To support this end to end approach the Unilever Sustainable Living Plan was introduced by CEO Paul Polman in 2010. In this plan the strategy is set out how Unilever will halve their environmental impact while doubling the business until 2020. The three main pillars of the USLP are to improving health and well being, reducing environmental impact and enhancing livelihoods. These three pillars are divided into seven commitments and around 60 time-bound targets (Figure 4 and Appendix 1: Unilever Sustainable Living Plan commitments and targets) (Unilever, 2012).

Figure 4 USLP pillars and commitments (Unilever, 2013)

Within the commitment of greenhouse gases Unilever examined the amount of greenhouse gas that is used in the different parts of the supply chain. Figure 5 shows that most of the greenhouse gas is used in producing the raw materials and during consumer usage. By for example procurement standards and product innovations Unilever is trying to reduce this negative side effect of their products. Beside these areas, manufacture and transport are also very important since they can be used to set an example and are in the direct sphere of influence for Unilever. Although 2% might not seem a lot, it is good to realize that the trucks of Unilever in Europe form only a small part of this 2%. These trucks still drive an equivalent distance as twice the distance to the moon on a daily basis. So energy reduction in this area will have a significant impact.

Figure 5 Greenhouse gas footprint (Unilever, 2012)

It is clear that there is enough motivation for Unilever to conduct a research to decrease the energy consumption of their warehouses. For building this new warehouse the following question should be answered by this research: which sustainability option should be chosen to achieve the sustainability target in a cost efficient way?

2.2 Research goal

As described in the previous section, there is a desire within Unilever and K+N to create a better understanding on how a warehouse could be as sustainable as possible. The words 'as sustainable as possible' are chosen since there are some limitations to the extent to which the new to build warehouse can be sustainable. During this research the limitations will get more visible but there are two large limitations that can be indicated already on beforehand, namely: the cost of the warehouse and a desired performance rate of the warehouse. There are multiple stakeholders in the new warehouse project that work together to ensure the performance and together should bear the costs of the project. Therefore the goals of this research are:

- *Find possible options to ensure a warehouse where sustainability meets performance.*
- *Give insight in forms of collaboration between parties in a complex and multi-user project to realize sustainability.*

To reach the goal, it is necessary to formulate research questions that address concrete research areas. In the next section the research goal will be translated into a research question and sub questions. Answering these questions should help to achieve the research goal.

2.3 Research question

There are a lot of benefits if the warehouse is build sustainable, for example less energy costs and a better employee satisfaction. Those benefits will take, in most cases, a higher initial cost compared to non-sustainable solutions. For some of the sustainable options the payback period will even be longer

than the duration of the contract between the parties involved. Especially for those options it is important that the option is not discharged only based on cost concerns. To make a deliberate choice between those sustainability options there are more selection criteria. Those criteria will be clarified later in this report.

Who should invest? Who is bringing the big part? And how should revenues be allocated?

To realize the highest (but realistic) level of sustainability in this multi-user warehouse, collaboration is needed. But as the questions above suggest this is not that easy. Horizontal and vertical collaboration exist in many forms and is not set up overnight. For some of the most sustainable options collaboration between multiple parties, with different business goals, is essential. In this report the sustainable options for which this applies will be identified. Ways of horizontal and vertical collaboration will be investigated and recommendations will be made about the most suitable ones. In order to find the options and collaboration models the research question will be:

How can the new Kuehne + Nagel warehouse in Tiel be built in a sustainable and cost efficient way and what organizational structures could be used between parties to realize complex sustainable options?

To come to a good and complete answer to the research question, the following sub questions will be answered:

Sub question 1. What are options to build the new Kuehne + Nagel warehouse in a sustainable way?
Sustainability is a broad concept with many options that can be used to make the new Kuehne + Nagel warehouse more energy efficient but also a more pleasant place to work. Multiple sources like best practices, interviews and a literature review provide options to make a warehouse more sustainable.

Sub question 2. What are evaluation criteria for those options?
To make a substantiated choice of the options that should be implemented in the warehouse evaluation criteria are needed. The expertise of Kuehne + Nagel extracted during workshops is used to formulate these evaluation criteria. The different criteria can have a different weighting.

Sub question 3. What options should be implemented based on the evaluation criteria?
Scoring of the options is based on practical knowledge within the work stream and where needed completed by a research conducted by an external real estate consultancy firm. The scoring via evaluation criteria will give each option a score. If an option scores above a certain limit it will be recommended to be implemented in the new to build warehouse. For some of the options extra research is needed to score the evaluation criteria and give deliberated recommendations. These are options that require a higher initial investment and need an implementation plan to support their recommendation for example wind turbines or solar panels.

Sub question 4. What are key success factors and limitations for sustainable inter-firm collaboration in a multi-user (horizontal as well as vertical) project?

The options that require higher initial investments will be done in an inter-firm collaboration because the solutions are also for multiple users, risks can be shared and expertise from multiple companies can be used. To make the sustainable inter-firm collaboration a success, experiences from other collaborations are gathered. To find possible key success factors and limitations examples from literature and practical research are used.

Sub question 5. What capital and organizational structures could be used, for the sustainability options with high initial investments, in a multi-user project?

From the previous questions it became clear that investments should be made and that collaboration is needed. Inter-firm investments are a form of inter-firm collaboration that can be used in this project. For these options with higher initial investments capital structures are needed to allocate costs and revenues between multiple parties. The legal form together with the agreements between parties can be considered as the organizational structure. To find possible capital and organizational structures literature and practical research (case studies and interviews) are used.

Sub question 6. Which structure suits the needs of the new Kuehne + Nagel warehouse best?

A recommendation based on the characteristics of the new Kuehne + Nagel warehouse is desired. Therefore a comparison between the found structures and the characteristics of the new warehouse gives us the foundation for conclusions and recommendations. The pros and cons of the different structures are named and examples are given. Based on this comparison and the characteristics of the new warehouse recommendations are given. The collaboration between the parties will be complemented by key success factors and learning points from previous projects and the literature review as described in sub question 4.

2.4 Research method

In this section the research method is clarified. The different steps in the research are placed in order of execution and are briefly explained.

The research design is based on the methodological sequence within the analysis of inter-firm energy supply concepts as described by Fichtner, Frank, & Rentz (2004). This method is able to deal with two difficulties, namely; the insufficient economic and technical data and existing interdependencies between options and parties. This research is conducted during the pre-construction phase of the new warehouse. Consequently not all technical data is already available. In addition to this most of the payback periods of the options are highly dependent on a variable energy price. Some investments are part of construction while others are not warehouse bound. Also some options exclude others. This implies interdependency between the options and different parties involved. In this methodological sequence, as shown in Figure 6 first the theortical options are gathered. Subsequently there is a technical analysis of these options followed by an economic and ecological evaluation. These steps are translated to the new Kuehne + Nagel warehouse situation. In the first step of the research sustainable options are gathered. Thereafther the options are scored based on technical, economic and ecological evaluation. For the different sustainability options, named future senarios by Fichtner, Frank, & Rentz, desk research, literature review, interviews and case studies are performed.

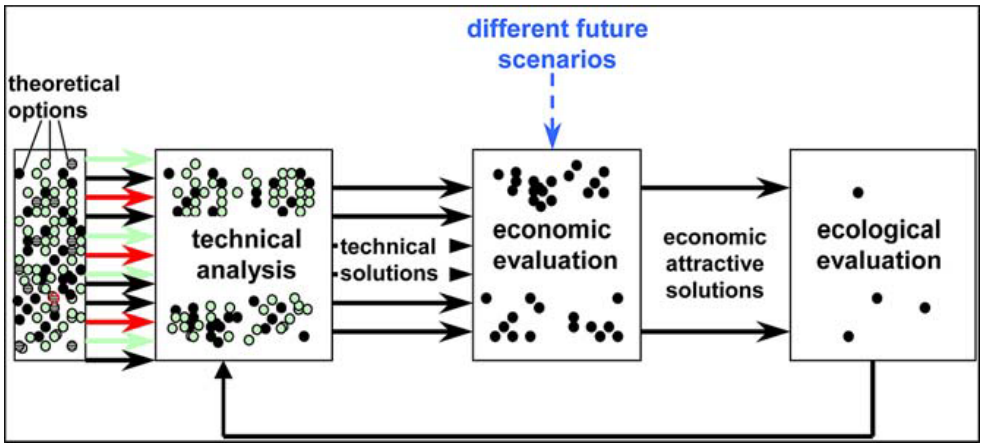


Figure 6 Overview of the methodological sequence within the analysis of inter-firm energy supply concepts (Fichtner, Frank, & Rentz, 2004)

2.4.1 Desk research

In order to find the answer to the first sub question the research will start with finding and evaluating possibilities to make the warehouse sustainable while maintaining or improving performance. Those options will come from different sources like literature, best practice booklets of Unilever, interviews with different practical experts and the BREEAM-NL assessment directives. Since the technical side of sustainability options is not the field of expertise of the researcher, limited information about this technical research is elaborated on in this thesis. To compose the scoring criteria and score the options the practical expertise of Kuehne + Nagel and the research by a real estate consultant are used. As a result of this process the options are placed in one of the three categories (Do, Research, Don't). In case of a 'Do' there is no discussion needed; the costs are low, the efficiency is high and it does not affect the operation. An example for a 'Do' option is a thermografic assessment of the warehouse in which the insulation of the warehouse is tested. About a 'Don't' option there should also be no further discussion. In these cases it could be that the investment is too large for the return on sustainability or the option affects the operation in a negative way. An absolute 'Don't' is for example a combined heat and power installation which has a payback period of more than a century. Options with a 'Research' score are options in which large initial investments are required, solutions where there are different options of which only one can be implemented or options where responsibility and ownership are not completely clear. The second part of this thesis is devoted to this last category of options. The options with a 'research' score will need further technical research as well as possible capital and organizational structures to exploit those options in a multi-user project. One of the research options in this research is the construction of a wind turbine. For this option a lot more information like payback period, permits and power redelivering is needed and also a capital and organizational structure is needed to consider such a large investment with multiple parties.

2.4.2 Literature research

This research can only be a useful contribution to the existing body of knowledge on sustainable warehousing if it acknowledges what is already known and extends this knowledge in some way. A literature review is conducted to identify what is known and what isn't. In the literature existing models and constructions are found, which can be used in practice in this situation.

Basically, we performed a literature study in three different areas, namely: sustainability options, inter-firm collaboration and inter-firm project investment. Literature was searched for possible sustainability options that could be applied to the new Kuehne + Nagel warehouse. To collect success factors for inter-firm collaboration literature about two different types of logistic inter-firm collaboration were reviewed, namely *eco-industrial parks* and *freight villages*. A literature review was also done for inter-firm project investment, a specific form of inter-firm collaboration.

Important in a literature research is that multiple sources are used (Scopus, Web of Science and maybe an existing literature review) as well as the right search terms. These search words can be used to filter the useful articles. Possible extra search words can be used to narrow the number of articles down even more. The third shift will be based on the review of abstracts based on inclusion and exclusion criteria. Table 1 will be filled such that the literature review can be repeated by anyone, anytime.

Sources	Scopus, Web of Science, existing literature review
First shift	search words:
Second shift:	extra search word:
Third shift	abstract-review based on inclusion and exclusion criteria

Table 1 Research method

With the selected literature a synthesis process should take place. In case of the literature review on inter-firm networks and investments the result of this synthesis will be a list of possible capital and organizational structures and success factors for horizontal and vertical collaboration that could be applied to the new warehouse.

The depth and extensiveness of the different literature reviews is based on the motivation for the review and the expected application of the conclusions. In case of the *sustainability options*, literature is used to gather different options that can be assessed. In this case no conclusions or recommendations are made and it is not a requirement to contribute to the existing body of knowledge. In case of the examples of *inter-firm networks* the review already has more depth because the goal is to find key success factors and limitations. The success factors and limitations of eco-industrial parks and freight villages are mostly practical in nature and are not all applicable to the warehouse. The reason for this is due to the fact that Eco-industrial parks and freight villages are of a greater magnitude and are a sort of future state of inter-firm logistics. The findings of this literature review are used to describe the potential and obstacles of inter-firm collaboration and also possible ways to form these collaborations. Seeing the Eco-industrial parks and freight villages as a possible future state of the new Kuehne + Nagel warehouse project the findings are more exploratory than directly applicable. The review of literature about *inter-firm project investments* is more extensive. This is because the expectation is that the conclusions and recommendations of this review will be directly applicable in this project.

2.4.3 Case studies and interviews

From the network of Unilever and Kuehne + Nagel, inter-firm projects were identified that have similarities with the new warehouse project. Those projects are used as subject of the case studies. First of all information is gathered via the internet. Then, actors in these projects are interviewed to get more information about their project and their experiences. The interviewees are listed in Table 2. The

information gathered is about the formation of the inter-firm collaboration and the structure of this collaboration including questions about investments, risk and parties involved. There were also questions asked about learning, success factors and limitations of the project. With the answers from the interviews, it was possible to compare the statements and models given in the literature and the ones used in practice. The interview questions for the interviews can be found in Appendix 2 Interview questions.

Name	Company	Inter-firm project
Cedric Liekens	Colruyt	Northwind
Bernd-Oliver Mager	Unilever DACH	Solar panels DC Heilbronn

Table 2 interviewed project experts

To summarize the approach for this research Figure 7 shows a schematic overview.

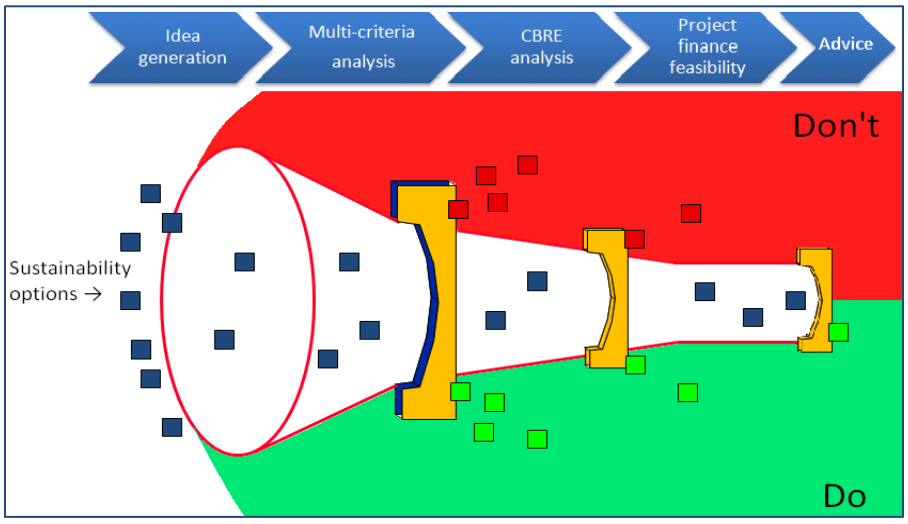


Figure 7 Methodology funnel

2.5 Research scope and limitations

This research is aiming to find options to build a sustainable warehouse in Tiel for HPC products of Unilever and other manufacturers. For some of those options a collaboration model is needed for implementation. In this section it is explained what the scope of this research is, in other words what kind of sustainability options are reviewed and to what extent advice is given about possible collaboration models.

Scope

In this research sustainability options for the new Kuehne + Nagel warehouse are the central topic. This research had a fixed start and end date therefore a certain scope was chosen. As was found in the literature and other sources there are a lot of possibilities to make a building more sustainable. At the moment of starting this research one of the options that has a big impact on the CO2 emission of the warehouse activities was already chosen, namely the location. The location on industrial site of Medel in Tiel was already defined for several reasons of which sustainability was one.

Due to time constrains and the timing within the development phase of the new warehouse in Tiel only sustainability options were considered that were related to the building phase or had to do with generating sustainable energy. Options that should be implemented during the operational phase or that have impact on the maintenance of the warehouse are therefore out of scope. One of those areas that can have a large impact during the operational phase is for example transport.

Since the research is commissioned by Unilever and the main research topic is the new Kuehne + Nagel warehouse only possible options suitable for this warehouse are considered. There are a lot of sustainability options for warehouses with cooling and freezing purposes but these were not appropriate for the new warehouse where home and personal care products will be stored. There were also options that were not applicable since Medel did not meet the location requirements for those options.

Some of the options that are assessed are simple to implement while other need high investments and collaboration models. Two of those last options are for example PV-panels and a wind turbine. For those options recommendations about possible capital and organizational structures are given. These recommendations are not yet a readymade plan with amounts of investment, percentages of debt and equity and legal forms. During the literature study and interviews with practical experts it became clear that this is not possible. A large part of the capital and organizational structure is defined during the negotiations and discussions with participating parties. The scope of this research is not to be part of these negotiations and discussions as some sort of mediator but to give advice on points of concern and possibilities. Also part of this research is to filter experiences from practice and give suggestions for starting possible project finance. To consider project finance advantages and disadvantages are named but also points of interest that can be used even if project finance is not chosen.

Also only existing options are in scope of this research. Some of the options are tailored to the new warehouse but no inventions came out.

Limitations

The scope already made clear some of the limitations of the research. Besides the decisions that were made to make the research manageable there are also some limitations on this research. First there is the limited knowledge of the researcher about technical aspects of sustainability options. A lot of information was gathered via Kuehne + Nagel experts, the real estate service provider and written sources. This also causes the fact that only a high-level description of certain options is given in this report and recommendations about technical aspects are omitted.

Another limitation is the fact that interviewees could not go into much detail about financing because of legal restrictions and confidentiality.

A limitation of this report is its readability since two researches, namely sustainability options and inter-firm project finance, are combined. Besides this the audience for this report is very diverse causing a dilemma between depth and technical aspects on the one hand and comprehensiveness on the other. To guide all readers through the research a reading chart is added in Figure 8.

Deliverables

Unilever has developed a road map to decouple their business growth from environmental impact. In this plan an end to end approach for the complete supply chain of their products is described. One of the important elements of this supply chain is distribution of Unilever products from the SUs and copackers to the customers. A part of this distribution is storage, picking and cross docking which all happens in warehouses. Possible ways and guidance is needed to set an example, reach the targets and make this part of the supply chain more sustainable.

This research will benefit Unilever by identifying possible sustainability options for their warehouses and specifically the new Kuehne + Nagel warehouse in Tiel. A list of possible options and selection criteria provided in this thesis will help to make Unilever's warehousing activities more sustainable.

Secondly, this research gives guidance in the process of project finance to realize large sustainable investments in a multiparty concept. Stakeholders, risks and success factors are identified and directions for an organizational and capital structure are given.

2.6 Outline of the report

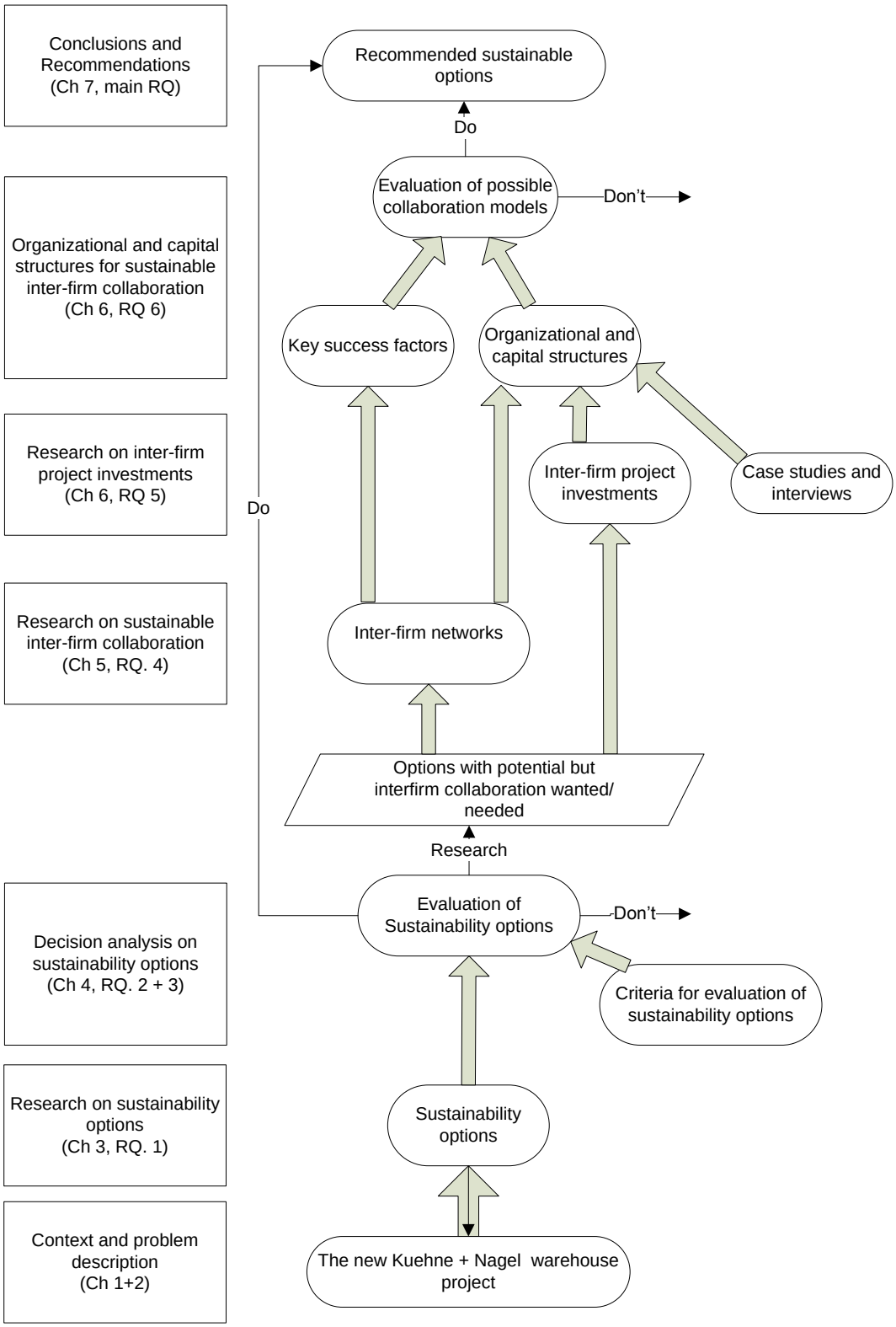


Figure 8 Reading Chart

3 Research on sustainability options

In the first two chapters we described the research motivation and approach. Summarized, the motivation is that the current warehouse in Raamsdonksveer does not satisfy the growth and sustainability ambitions of Unilever any more. Together with the logistic service provider Kuehne + Nagel a new warehouse will be built. This new warehouse, which is called the Madagascar warehouse, will be built on Medel industrial site in Tiel. This new Kuehne + Nagel warehouse should be a warehouse where sustainability meets performance. So an efficient and effective operation with minimum environmental impact and a positive influence on the employees. To make the warehouse more sustainable, options are gathered and reviewed. This chapter shows sustainability options applicable to this warehouse found in the literature and other relevant sources.

In the search for options the applicability to the new Kuehne + Nagel warehouse in Tiel was already taken into account. Therefore we will briefly describe some of the most important specifications of the warehouse. It will be a multi-user warehouse that consists of three parts: the warehouse part, an office part and the repack area: the mezzanine. The warehouse will be operational 24 hours a day, 5 days a week, all year long. The total floor space of the building will be about 37,000 m^2 and the height of the building will be 14 meter. The main purpose of the building is storage and distribution. A cooling or frozen area is not needed for the storage of the home and personal care products. For some of the products like deodorants a special area is needed which complies with the Alternative Dispute Resolution (ADR). This resolution sets requirements for the storage of dangerous goods. With these specifications our search for sustainability options started.

There has been a lot of research on sustainable development in the last two decades. This research was not only conducted by pure researchers, also companies themselves have taken a critical look at their ways of doing business and how to adopt sustainable development in their processes. For this research we wanted to collect all sorts of sustainable development options to make the new Kuehne + Nagel warehouse as sustainable as possible.

First of all a literature scan was used to find possible areas of sustainable development of a warehouse. We conducted a search as described in Appendix 3: Literature search on sustainability options. The field of green/sustainable building is a research area that shows a growing attention in the last decade. The reason for this is the energy crisis and urgency of global warming and other environmental concerns (Han, 2010). Also the zero carbon targets from governments and other regulations enlarge attention for this research area (Rai, 2011). The attention for sustainable building and development is further increased by the scarcity of natural resources and the positive impact of sustainability on businesses (Ortiz, Castells, & Sonnemann, 2009). The variety of areas that was described by the articles found was large. Some of the papers were regarding management of the building process like design strategies (Rai, 2011) and processes of construction (Fieldson & Siantonas, 2008), while others had much more specific solutions to make a warehouse more sustainable. To reduce the CO2 emissions Jack (2007) stresses the importance of the location of the warehouse while most of the other authors give recommendations about cooling, heating and lighting of the warehouse. Day lighting, use of natural

ventilation and occupancy detectors are just a few of the solutions named (Han, 2010), (Giulani, 2009), (Lamb, 2008), (Roy, 2010).

From the literature scan it became clear that there were very detailed and technical explanation of specific options and no overviews with multiple applicable options. One example of such an option is the paper by Burek & Habeb (2007), who describe the heat transfer and mass flow of two specific air heaters. For this research such specific information per option is not relevant. We searched for more general information and possible applicability to a warehouse or comparable building.

To get an overview with multiple applicable options for the project also other sources were used. Sources that were used are best practice booklets of Unilever, the K+N warehouse in Hamburg and interviews. From those sources a lot of options were generated. Also the BREEAM-NL assessment directives were used. BREEAM-NL is an assessment method to determine the sustainability performance of buildings. From the directives of this assessment method very useful options could be gained.

To find options many sources were used that were of any relevance. Due to time restrictions and the specifications of the new warehouse this search is not exhaustive. It could be that not all new or less familiar options are included. By the repetitive character of many of the sources we are convinced that the most important options are included. Also the variety of sources used gives us the conviction that our search was extensive and thorough.

Most of the sources that were found suggest options for the demand or supply side. On the demand side it is about conservation of energy and improvement of energy efficiency while on the supply side it is more about the use of sustainable energy sources. This distinction is seen more often in the literature as well, where minimization or reduction of the demand is indicated as more preferable (Sarkis, 2003). For the new Kuehne + Nagel warehouse this principle is also valid but for the remaining energy requirement sustainable supply options are discussed.

Both demand and supply options that were found are assigned to their functional area such as heating, lighting, water, energy and waste. This classification in functional areas is used for two reasons. The first reason is to make sure that all important areas are covered. The second reason is to easily decide if different options enforce, counteract or overlap with each other.

To explain the classification and demonstrate the use of the sustainable options an example is given. From interviews and application in Kuehne + Nagel's warehouse in Hamburg it became clear that thermographic assessments can reduce cold infiltration and heat loss. When the warehouse is finished two types of thermographic assessments can be done. On a cold day or during the night/early morning the warehouse is heated and with a thermographic camera photos are taken from the warehouse. These photos could be taken from inside as well as outside. So one type concentrates on the cold coming in and the other on heat leaving the building. With these photos thermal bridges or air leaks in the structure can be detected. With this information directed repair can be done to minimize unnecessary heating. These assessments are a measure to minimize the energy demand of the building and belong to the functional area of heating. The full list of options and their classification is showed in Table 3 and some pictures of these solutions are showed in Figure 9.

Functionality	Sustainability option	Description
Heating	Insulation	Material to reduces unwanted heat loss or gain via the walls and the roof
	Thermographic assessment (inside out)	An assessment with infrared to inspect the leak tightness
	Thermographic assessment (outside in)	An assessment with infrared to inspect the coldness infiltration
	Trombe Wall	A sun-facing wall separated from the outdoors by glass and an air space, which absorbs solar energy and releases it selectively towards the interior at night
	Coloring of outside walls	Absorption of solar heat via outside walls which reduces the need for heating
	Coloring of the roof	Absorption of solar heat via the roof which reduces the need for heating
	Air curtains for loading docks	Blowers that turn on at open loading docks to reduces unwanted heat loss or gain via loading docks
	Inflatable seals for loading docks	Inflatable pads to reduces unwanted heat loss or gain via loading docks
	Central temperature regulation	Central control of the temperature in the different areas of the warehouse to reduce needless heating
	Humidity control	A system that controls the air humidity which reduce heating since less heating is needed with an optimal humidity
	Combined heat and power installation	A heat engine or power station that simultaneously generate electricity and useful heat which reduce the requirement for other forms of heating
	Heat recovery from ventilation	A device that provides fresh air and improved climate control, while also saving energy by reducing heating (and cooling) requirements
	Acoustic alarm for warehouse doors	An alarm that indicate when doors are open which result in unwanted heat loss or gain
	Green roof	A planted roof that gives extra insulation and a more sustainable appearance to the building
	Green façade	A planted façade that gives extra insulation and a more sustainable appearance to the building
	Solar thermal panels	Panels designed to produce hot water by absorbing sunlight
	Air/Ground Heat pump	A system that extracts heat from outside air or the ground
	VRF system	A system that uses a refrigerant as cooling and heating medium
	Under floor heating	A system that uses either electrical resistance elements or fluid flowing in pipes to heat the floor
	Radiation heating + fans	Infrared gas burners which heat is circulated via fans
	Air heaters	Devices that heat air via hot water which is then circulated via fans
Lighting	Determination of required light levels	An assessment of the required light levels to prevent needless lighting
	Determining most effective location of light sources	An assessment of the most effective location of light sources prevent needless lighting or too much light sources
	Windows (east and west side)	A transparent material that maximize natural light passage
	Daylight installations (skylights, solatubes)	An installations that maximize natural light harvesting
	Intelligent lighting/motion sensors	A system that switch off lights when an area is not occupied and re-strike instantly when there is movement, and dimmers to adjust artificial light output power to requirements
	Flooring with a reflective substance	Dye that brighten the space, helping reduce lighting requirements
	Ceiling with a reflective substance	Dye that brighten the space, helping reduce lighting requirements
	LED lighting	A lighting system that uses light-emitting diode (LED), a semiconductor light source
	Fluorescent TL5 lighting (high frequency and dynamic)	A lighting system that uses fluorescent lamps that does not flicker and gives natural/daylight-like light

Water	Motion sensors for taps and showers	Systems that make sure the water only flows when used/needed
	Double flush systems and flush disruptors for toilets	Systems that reduce the water usage per toilet visit
	Leak detection system	A system to ensure that there are no leakages in the pipelines and other water equipment
	Rainwater harvesting and usage of wastewater	A system that capture rain water which can be used for toilet flushers and cleaning
Energy	Power consumption (sub)meters	A system to know how much power is used and where this power is used
	Solar panels	Photovoltaic cells that generate and supply electricity with light energy (photons) from the sun
	Wind turbines	Devices that converts kinetic energy from the wind into electricity
Waste	Stimulating waste segregation	A way of working by which it is stimulated that waste is separated into different elements, this is environmental and economical profitable
	Compressing/cracking of waste	A way to reduce space utilization on the building side as well as in transport
	Origin of building material	A measure that sets a maximum radius and hallmarks that can ensure sustainable building materials

Table 3 List of sustainability options

Figure 9 Examples of sustainability options

Summary

In this chapter the specifications of the new Kuehne + Nagel warehouse in Tiel were given. A multi-user warehouse that will be built by WDP (developer) and exploited by Kuehne + Nagel (logistic service provider). In this warehouse, amongst others, the home and personal care products of Unilever will be stored and picked. To make this warehouse more sustainable a literature search was done to find sustainability options. Also other sources like best practice booklets, interviews and case studies were used to gather as much sustainability options as possible that could be applied to the new warehouse. These options aim to reduce the energy demand or supply sustainable energy for the warehouse. Both demand and supply options that were found were assigned to their functional area such as heating, lighting, water, energy and waste to make sure that all areas are covered and identification of overlap or counteract between options. All the applicable options are shown in Table 3.

4 Decision analysis on sustainability options

Chapter 3 shows the list of possible sustainability options. These options have to be evaluated to make a decision whether or not they should be recommended for implementation in the new Kuehne + Nagel warehouse. In this chapter the decision analysis method and associated evaluation criteria and their weights are determined. To recommend which of the options from chapter 3 are suitable for the warehouse an assessment of the options had to take place. This decision analysis is based on multiple criteria since there are multiple objectives and requirements to which the options have to apply up to a certain level. Multiple criteria decision making (MCDM) or multiple criteria decision analysis (MCDA) are generic terms for all methods that exist for helping people making decisions according to their preferences, in cases where there are more conflicting criteria (Løken, 2007).

For the analysis a small survey of decision analysis methods was done. Some of the most widely used models are the lexicographic model, linear assignment model and the decision analysis method by Kepner and Tregoe. These models differ for example on their (non)compensatory property and score/outcome. The lexicographic model is a non compensatory model that rank objectives and compare alternatives on those objectives starting with the most important one. The alternatives which satisfy the first criterion are evaluated with respect to the second criterion and if more than two alternatives satisfy this criterion, a third criterion is used and so on down the list of criteria until just one alternative is identified. Scores on a criterion cannot be compensated by the scores on other criteria (non-compensatory). For some of the criteria compensation is not allowed for the warehouse but we will also need some criteria which scores can be compensated. Also a clear ranking of the criteria is difficult. The basic idea of linear assignment method is that an alternative deserves a high rank if it has high scores on all criteria. In this method alternatives are ranked on each criterion (de Boer, 1998). Since there are many alternatives and these alternatives are not compared to each other but rather get a score whether or not we should recommend them for implementation, the linear assignment method is not useful. The method of Kepner and Tregoe is able to cope with a variety of options and does not rank criteria or alternatives like the lexicographical model and the linear assignment model. For the new Kuehne + Nagel warehouse a ranking of the options is not necessary since multiple options can be recommended. For this project only a recommendation of do or don't is significant. To give a score to the options the decision analysis method of Kepner and Tregoe is used (Hicks, 2004). Section 4.1 describes this decision analysis method of Kepner and Tregoe. The authors of this decision analysis method emphasize that the quality of the criteria and the evaluation of alternatives are crucial for a good decision. Therefore section 4.2 and 4.3 elaborate on the evaluation criteria and their weights. Section 4.4 is about evaluation all the options/alternatives on these criteria.

4.1 Decision analysis method

Kepner and Tregoe describe a stepwise decision analysis method. This method is used to make a decision which of the sustainability options are suitable to implement. The decision analysis process involves six steps, which are shown in Figure 10. The steps of decision statement and the generation of alternatives are already done. The decision statement is to 'Select options to build a sustainable warehouse in a cost efficient way' and the list of generated alternatives is showed in Table 3.

Figure 10 The Decision Analysis process (Hicks, 2004)

In the stages of selection and classification of objectives, criteria are selected to compare and evaluate the alternative (sustainable options), and the classification of those criteria into MUSTS and WANTS. MUST criteria are mandatory, that is, the alternatives must meet this requirement to be considered for recommendation. The MUSTS are used to make the initial screening of our alternatives – those not satisfying the MUST criteria are rejected. A MUST criterion is a non compensatory criterion: a (too) low score on this criterion can not at all be compensated for by (very) high scores on other criteria. WANT criteria are the features that we would like each alternative to possess, and which we can use to distinguish between the relative merits of the alternatives. The final tasks in this stage are to determine the relative importance of the WANTS criteria and allocate them a weight accordingly. This can be done by using a 1-5 scoring scale where 1 is not so important and 5 is very important.

The next step of the decision analysis method is the evaluation of the alternatives. For each WANT criteria a score is awarded. The scores are given as follows: Alternative X satisfies the objective – totally 5, very well 4, by more than half way 3, some 2, only a little 1, not at all 0 (Hicks, 2004). For each alternative the score on a criterion is multiplied by the weight of this criterion, the sum of these products is the total score. In this research the outcome of the total score places the alternative in one of the three categories; Do, Research or Don't. The alternatives that have a total score high enough, as defined by the sustainability and environment work stream of the Madagascar project, are recommended to implement right away. For the alternatives with a score in the Research category, further investigation is needed since the return on investment (in the broad sense) of those options is not very positive or negative. Where the Don't options are clearly a waste of money, time or efficiency.

The last step is to choose for one or more of the alternatives. For this research recommendations are the final outcome. The choice for the alternatives is with the decision makers of Unilever and Kuehne + Nagel together with the developer.

4.2 Evaluation criteria

In this section we describe the objectives/criteria of the decision analysis that were identified. These criteria are used to evaluate the options from chapter 3. This identification was done together with members of the steering committee. The steering committee consists of project leaders of the complete New Kuehne + Nagel warehouse and is the committee for whom this report with advice is meant. For these criteria the specifications of the warehouse, the mission (sustainability meets performance), the different elements of the term sustainability and the desire to make the efforts visible were used. During the identification of the criteria we kept in mind that those criteria should be relevant, clear, concise and consistent (Hicks, 2004). The order in which we present the identified criteria is random.

Improvement of the working environment

The working environment is about the working conditions of the people working in the warehouse building. The people working in the warehouse are divided over the office, co-pack area and the warehouse area. The warehouse will be occupied 24 hours a day, 7 days a week, all year long. This means that the working conditions have to be pleasant to work in. For this criterion heating systems are taken as example. A good working temperature in a warehouse is about 14 ^{o}C, for the office and co-pack area this should be 18 ^{o}C or higher. To be comfortable this temperature should be stable and there should be as little air movement as possible. Under floor heating gives a constant heating without air movement. This option scores higher on this criterion than for example air heaters where warmed air is blown through the warehouse.

There are also options that have no positive or negative effect on the working environment. These options get the average score of the options with a score on this criterion. Via this method their score is not positive nor negatively influenced by this criterion.

Low effort for implementation

For each option there is a different effort for implementation needed. Effort in this sense is not about costs, it is about the extra labor required to implement the option. There is a huge variety in effort for the different options. A high score on this criterion means that it takes not much effort to implement the option, this is a positive attribute of an option. The score is high if the extra effort is for example only in the sourcing process of the building materials, which is the case for ordering ceiling tiles that have a reflecting color. A wind turbine for example has a low score on this criterion because it costs a lot of effort to realize this option.

Low Costs

This criterion is about the costs associated with the sustainability option. In this cost component there are two elements; initial/purchase costs and maintenance costs. There is no distinction made between those components because these components have a very high correlation. A low score on this criterion means that the option has high costs.

Little negative impact on the operation

The slogan of the Madagascar project is ‘Sustainability meets Performance’. The goal is to find options that increase the sustainability of the warehouse while keeping performance at the same level or increase the performance. Options that have a negative impact on the operation score low on this criterion. Examples of negative effects could be that steps in the process will take more time or extra man-hours by implementing the option.

Increase ecological sustainability

The options are called sustainability options because they have to contribute to either the working environment or ecological sustainability of the new Kuehne + Nagel warehouse. Options that only improve efficiency of the warehouse are out of scope for this research. Ecological sustainability exists in many forms, for example the improvement of the energy efficiency, the production of green power or water savings. The effect on sustainability of the different options is explained in the description column

of Table 3. A high score on this criterion, which is positive, means that the solution makes the warehouse more ecological sustainable.

Increase marketable image

Not only the improvement of the working environment and carbon footprint of Unilever, Kuehne + Nagel and other participants is important. Also the possibility to show customers, consumers and others that effort for increased sustainability has been made is a requirement. During the building process and just after finishing the new Kuehne + Nagel warehouse a movie will be made to summarize the elements that make the warehouse more sustainable. The higher the score on this criterion the easier it is to demonstrate the contribution of the option to the sustainable character of the warehouse.

Increase BREEAM score

BREEAM (BRE Environmental Assessment Method) is the world's most widely used method of assessing, rating and certifying the sustainability of buildings. In the Netherlands the Dutch Green Building Council is the organization that appoints assessors and certifies buildings. There are five possible certificates that all indicate a different level of sustainability; pass, good, very good, excellent and outstanding. To get one of these certificates a minimum level of BREEAM points have to be obtained. A minimum score is needed for pass and the maximum for outstanding. There are strict guidelines for the number of BREEAM points that can be scored on different areas. These areas are: management, health, energy, transport, water, materials, waste, pollution, land use and ecology. A sustainability option with a high score on this criterion is likely to increase the overall BREEAM score of the warehouse.

These criteria were assessed on the MECE principle. This means that criteria should be Mutually Exclusive and Collectively Exhaustive. This principle makes sure that the criteria do not overlap and together test the alternatives on all important aspects. The criteria are collectively exhaustive by covering the 3 Cs (Customer service, Costs and Carbon), which are Unilever project pillars. The customer service is evident in the criterion of *little negative impact on the operation*. Costs are covered by the criteria of *low costs* and *low effort for implementation*. The third C of carbon is represented in the criteria of *improvement of working environment*, i*ncrease ecological sustainability*, *increase BREEAM score.* The last criterion of increase *marketable image* is the possibility to make the efforts visible, which was a request of the steering committee. To make sure that the right criteria were used the identification was done together with members of the steering committee. They concluded that the relevant aspects were covered by these criteria.

The mutually exclusiveness of the criteria is a bit more difficult to explain. *The low effort for implementation* consists of all the extra work and does not include direct costs. This makes this criterion exclusive from *low costs*. The *little negative impact on the operation* does not overlap in any way with the other criteria. *Increase marketable image* has similarities with the criteria named for carbon but an increase in this score is independent of the scores on these criteria. The heat recovery from ventilation exemplifies this: this option is not easily made visible but increases the ecological sustainability, enriches the working environment and increases the BREEAM score.
The three criteria named to cover the carbon pillar are all required but less mutually exclusive. An increase in ecological sustainability does almost always increase the BREEAM score, but there are

exceptions. A wind turbine that is not placed on the lot besides the warehouse building is not included in the BREEAM assessment but is certainly increasing the ecological sustainability of the warehouse. The fact that there is some overlap in these three criteria is taken into account in the weight of those criteria. This weighting is explained in the next section.

4.3 Weighting of criteria

MUST

Section 4.1 describes that the criteria can be subdivided into MUSTS and WANTS. As already briefly explained in section 4.2 the focus is on options that increase sustainability in its broadest sense. This is measured by the 'increase ecological sustainability' and 'improvement of working environment'. To make sure every option we recommend has a minimum contribution in making the warehouse more sustainable the minimum score of the sum of these two criteria has to be 6.

It was also mentioned before that the slogan of the new Kuehne + Nagel warehouse is 'performance meets sustainability'. To ensure that the performance is not harmed all options MUST score a four or five on the criterion' Little negative impact on the operation' to be considered on the WANT criteria.

- *Increase ecological sustainability and improve working environment (minimum score of the sum is 6)*
- *Little negative impact on the operation (minimum score is 4)*

WANTS

For all WANT criteria weights have to be determined. This was done together with a building expert of Kuehne + Nagel who was also involved with the building process of warehouses in Zwolle and Utrecht (the Netherlands). Herewith the overall goals of the warehouse and the missions of parties involved were also taken into account.

It is described by Kepner and Tregoe that it is quite reasonable for a criterion to be both a MUST and a WANT. In this case the criteria 'increase ecological sustainability' and 'improve working environment' were used as MUST criteria and are also used as WANT criteria. This is because more sustainable options are more preferable. With 'low costs' as the most important WANT criterion and 'low effort for implementation' as the least, the complete list is as follows.

- Improvement of the working environment
- Low effort for implementation
- Low Costs
- Increase ecological sustainability
- Increase marketable image
- Increase BREEAM score

Options that could not be given a score on these criteria based on the expertise of the K+N expert, because of complexity or limited available information are put into the research category. For these options further research is needed to give a grounded recommendation. To give a recommendation about mutually excluding options both the score as well as cost efficiency are taken into account. For some of those options also research is required, for example in choosing a lighting system. This could be or T5 lighting or LED lighting, but not both. Before the choice between those two is made, more information about LED lighting is needed.

4.4 Categorization of sustainability options

The scoring of the options that were found in chapter 3 on all of the MUST and WANT criteria mentioned in section 4.2 and 4.3 was done together with an expert from Kuehne + Nagel. The researcher was responsible for gathering the sustainability options and the identification of the criteria together with the steering committee. For the scoring the knowledge of an expert was needed. To score the options the researcher and the expert worked together. With the technical knowledge of the expert and the insight of the researcher on the topic a discussion led to the scores on all criteria for the alternative. To illustrate the scorings method, an example for one of the sustainability options is given.

One of the sustainability options found in the literature and other sources was determination of required light levels. This is an assessment of the required light levels to prevent needless lighting. This option is first evaluated on the MUST criterion *little negative impact on the operation*. The effect on the operation is very positive since enough light is required to have a smooth operation. If the required light level is determined for the different operations there will always be enough light for those operations. To get the score of the other MUST criterion we need the sum of two WANT criteria, namely *improvement of the working environment* and *increase ecological sustainability*. The sum of the scores on these criteria gives the score for the *total increase in sustainability*. The score *for improvement of the working environment* is high (5) since light is an important factor for a pleasant and healthy place to work in. Also the score for *increase ecological sustainability* is high (5) because if this options is applied there is no waste of energy on to much lighting. Another argument of this high score is that the option itself is only a very good assessment of the light plan and some testing, so no extra (harmful) material is needed. Both MUST criteria have a threshold that is non-compensatory. So the score on *little negative impact on the operation* has to be 4 or 5, otherwise the alternative is rejected and not recommended to the steering committee. In this case the determination of required light level scores the maximum score on both criteria and does therefore satisfy the MUST criteria.

The determination of required light levels is also scored on the other WANT criteria such as *low costs* and *increase in BREEAM score*. With a score on every criterion and the weights of those criteria, as described in 4.3, a weighted score for the option can be calculated. In this case the weighted score for the option is 63 points. This means that our advice is ‘Do’, which means that we recommend to include this option in the building preferences. The scoring of this option is shown in Figure 11.

	MUSTS		WANTS						Score	
	Little negative effect on the operation	Total increase in sustainability	Improvement of the working environment	Low effort for implementation	Low costs	Increase ecological sustainability	Increase marketable image	Increase in BREEAM score	Weighted score	Advice
Determination of required light levels	5	10	5	4	3	5	3	4	63	Do

Figure 11 Scoring the sustainability option *determination of required light levels*

The scoring table of all the options can be found in Appendix 4: Sustainability options decision analysis. The outcome of the decision analysis is summarized in Table 4.

	Do	Research	Don't
Heating	Insulation (Rc 3.5)	Combined heat and power installation	Trombe Wall
	Thermographic assessment (inside out)	Solar thermal panels	Coloring of outside walls
	Thermographic assessment (outside in)	Air/Ground Heat pump	Coloring of the roof
	Air curtains for loading docks	VRF system	Inflatable seals for loading docks
	Humidity control	Under floor heating	Central temperature regulation
	Heat recovery from ventilation		Green roof
	Acoustic alarm for warehouse doors		Air heaters
	Green façade		Flooring with a reflective substance
	Radiation heating + fans		
Lighting	Determination of required light levels	Ceiling with a reflective substance	Daylight installations (skylights, solatubes)
	Determining most effective location of light sources	LED lighting	
	Windows (east and west side)		
	Intelligent lighting/motion sensors		
	Fluorescent T5 lighting (high frequency and dynamic)		
Water	Motion sensors for taps and showers		Leak detection system
	Double flush systems and flush disruptors for toilets		Rainwater harvesting and usage of wastewater
Energy	Power consumption (sub)meters	Solar panels	
		Wind turbines	
Waste	Stimulating waste segregation		
	Compressing/cracking of waste		
	Origin of building material		

Table 4 Categorization of sustainability options

For the 'Do' options we recommend to adopt these options into the blueprints of the new Kuehne + Nagel warehouse. The 'Don't' options are expected to not give the desired returns on investment, sustainability or the visibility of their sustainability and are therefore discouraged to implement. The options in the research category are explained in a bit more detail below.

Research options

Research options are options that had a score that was not convincing enough to directly recommend 'Do' or 'Don't' or there was too little information to give a grounded recommendation. For those options a global real estate service provider (CBRE) was hired to do research on the technical aspects of those options. In this section the most important findings are presented and where possible a shift to 'Do' or 'Don't' is indicated.

Combined heat and power installation

A combined heat and power (CHP) installation is used to simultaneously generate electricity and heat. A CHP installation is mostly used in buildings with a large and simultaneous demand for heat and electricity all year long like swimming pools and greenhouse complexes. To be efficient a CHP installation should have a minimum of around 5000 full load hours per year. Because the temperature in the warehouse is relatively low, these 5000 full load hours per year will not be reached. Therefore a CHP installation is not suitable for this type of building and is shifted to the 'Don't' category.

Solar thermal panels

Solar thermal panels or solar collectors are used to preheat warm tap water for wash and locker rooms. This option contains solar collectors, water pipes, a pump and a buffer tank. There is not much warm water usage in a warehouse and the estimated payback period is 38 years for this option. The estimated life time of the warehouse is 30 to 40 years. Therefore this option is discouraged and shifted to the 'Don't' category.

Air/Ground heat pump + under floor heating

Heat generation can (partly) be realized with a heat pump. This heat pump is electrically driven and can generate the largest part of the required heat per year. The heat pump needs a medium to extract its heat. This medium can be air, surface water, ground or soil. In wintertime the heat requirement of the warehouse is at its peak. Since the ground has the highest temperature during winter it is energetically most attractive to use this medium. The size and location of the building are very suitable for the use of open sources in the ground. To extract and infiltrate water from the ground (> 10 m^3/hour) permission is needed from the province, which will take 6-9 months. The option that is advised by CBRE, is to make use of a ground heat pump for the office and the mezzanine (an intermediate floor between main floors of the building) and not for the storage area. This is because the storage area does not have any cooling requirements and the temperature is relatively low. For this reason the potential savings do not weight up to the extra investment. For the office and mezzanine the floors will need a warming technique based on water like radiators or under floor heating. Since under floor heating is more efficient this option is recommended.

The pros of a ground heat pump are the relative short payback period (approx. 15 years), its sustainability (move from gas to electricity), the free cooling, and the possibility for public subsidy. Cons are the time to get a permit (6-9 months), the fact that ground and water have to be monitored, and that there are higher operational costs involved.
This option is to be positively considered if funds are available. To make those funds available inter-firm collaboration and investments are elaborated on in chapter 5 and 6.

VRF system
This technique is, like the ground heat pump, used for heating and cooling of the building. VRF uses refrigerant as the cooling and heating medium. The system has outdoor condensing units that are connected to indoor fans. By operating at varying speeds, VRF units work only at the needed rate allowing for substantial energy savings at part-load conditions. Heat recovery VRF technology allows individual indoor units to heat or cool as required, while the compressor load benefits from the internal heat recovery.
Since a VRF system has the same purpose as a ground heat pump only one will be installed. The ground heat pump is more sustainable but also more expensive. CBRE advice is to install the ground heat pump if possible or else use a VRF system.

Ceiling with a reflective substance
This option is not recommended since both possible lighting systems have light beams that are 'sent' downwards direct (LED) or via mirror optics (HF-TL5). So a ceiling with reflective substance would not have any effect. This option is shifted to the 'Don't' category

LED lighting (storage area)
Lighting the storage area is responsible for about 32% of the energy consumption of the building when high frequency TL5 is used. HF TL-5 is already a significant improvement in energy consumption compared to the current lighting of the warehouse in Raamsdonksveer. To make the lighting system even more sustainable LED lighting could be used. The payback period of the extra investment is approximately 7 years and a saving of 10% of the total energy consumption of the building could be realized. The downsides of this technique are that it is still quite new and the expected light requirements in lux at the working level are not met.

PV panels
The size of the new warehouse is large enough for solar panels or PV panels. These panels convert solar energy into electricity. By installing PV panels the amount of purchased energy can be reduced. The more panels are installed the larger the output but also the amount of electricity that is redelivered to the power grid. This is less financial favorable as using the power yourself. Because of this effect there is a tipping point in the number of years for the payback period. The most favorable is the option with 1000 m^2 of PV panels, which has a payback period of 15 years. This option will cost around € 225.000.

Wind turbines

Wind turbines can be placed on the estate of the new Kuehne + Nagel warehouse or somewhere else. If placed next to the warehouse, permission is needed from the municipality. Wind turbines are available in multiple sizes. In principle, higher and larger wind turbines have a relative higher yield than smaller ones. On the other hand, just like PV panels, the power that isn't used will be redelivered to the power grid but is less profitable. The investment in an 85 meter high wind turbine with a rotor diameter of 70 meter is € 1.1 million and has an estimated payback period of around 15 years.

In the assessment of those options CBRE used a basic building with basic installations. This basic building is based on the principles of a standard building as developed by WDP and the additional point from the building requirements made up by WDP and K+N. In the assessment of the options mentioned above CBRE did not took into account that combinations of options might result in lower gains. As described above the research of CBRE made clear that some of the options are not suitable for a warehouse or are not as sustainable as initially thought. There were also options that got a positive recommendation as an outcome of the research, these are:

- Ground heat pump + under floor heating (alternatively VRF system)
- PV panels
- Wind turbine

For the options mentioned above a positive recommendation is given by the real estate service provider (CBRE). We make a distinction between these options based on the fact of the option being integrated or not in the building. This distinction is important because those options integrated in the building logically require a different form of investment. In those cases the building developer is likely to be the one investing. This can result in passing in some form. The options that is classified as integrated to the building is the heating system (a VRF system or a ground heat pump)

The other options are potential options for project finance because their use is not completely linked to the building. Electricity can for example be transferred or redelivered to the grid. Other characteristic of project finance are the singularity, the specific organization structure and the multiparty concept. To realize the large investments in a multiparty concept, what the new Kuehne + Nagel warehouse is, is complex. There are potential benefits for multiparty cooperation, for example a smaller investment per party and shared risk, also the expertise of multiple parties can be used. To give also advice about these options a further research on inter-firm collaboration is performed and discussed in chapter 5. In this chapter general success factors and limitations are summarized. As mentioned before, a large investment is required for these options therefore a specific form of inter-firm collaboration, inter-firm project investment is covered in chapter 6.

Summary

To assess the sustainability options described in chapter 3, a decision analysis was performed. The decision analysis method used was the method of Kepner and Tregoe. This method was chosen because of its ability to cope with a variety of options and does not rank criteria or alternatives. A ranking is not necessary, only a score per option is needed to make a founded recommendation. The method of Kepner and Tregoe works with MUST and WANT criteria. The MUST criteria are criteria that require a

minimum score of an option on this criterion to be considered as possible recommendation. The MUST criteria for this decision analysis were *little negative impact on the operation* and *Increase sustainability (ecological and the working environment)*. WANT criteria are the features that we would like each alternative to possess, and which we can use to distinguish between the relative merits of the alternatives. The WANT criteria and their weights for this analysis were: improvement of the working environment (2), low effort for implementation (1), low costs (5), increase ecological sustainability (4), increase marketable image (2), increase BREEAM score (2).

The result of our decision analysis was a score for every sustainability option. The scores were than coupled to an advice: Do, Research or Don't. For the 'Do' options we recommend to adopt these options into the blueprints of the warehouse. The 'Don't' options are expected to not give the desired returns on investment, sustainability or the visibility of their sustainability and are therefore discouraged to implement. For the options in the research category more information is needed to give a grounded advice. This information was gathered in co-operation with CBRE (real estate service provider). From this analysis a wind turbine and PV panels are interesting options but further research is needed on inter-firm collaboration and inter-firm project investment to realize these options.

5 Inter-firm collaboration for sustainability

The reason for a literature study on sustainable options was to get feeling with the subject and find potential options for building a sustainable warehouse. The reason for the literature review on inter-firm collaboration is to give more grounded advice in relation to the different sustainability options that need inter-firm collaboration to be realized. The research on inter-firm collaboration gives an embedding for the inter-firm project investments that is described in the next chapter.

Early research from for example (Das & Teng, 2000) and (Dyer & Singh, 1998) suggest that strategic alliances or relationships between firms achieve competitive advantages. Reasons for these competitive advantages are the ability to gain access to other firms' valuable (and complementary) resources or assets, inter-organizational learning and lower transaction cost. The multi-user warehouse gives the opportunity for such alliances and relationships.

The reasons for inter-firm participation named by (Fichtner, Frank, & Rentz, 2004) are concentration on core competences, realization of synergies, specialization, cost and time advantages. Fichtner et al. further state that the inter-firm concept is used rather infrequently for ecological reasons, but the article suggests that there is a lot of ecological potential in inter-firm networks. In their article, the inter-firm energy supply concept is leading, which shows similarities with sustainable options in this research. The possible competitive advantages for energy supply are economies of scale, possibilities for joint financing, less dependency on the supply market and more stable demand of energy. This ecological potential is also described by (Lin & Darnall, 2010) in relation to address complex environmental issues via strategic alliances. In these strategic alliances valuable information and opportunities can be shared between participating firms, firms have access to resources, and assets owned by different organizations can be complementing.

Before the competitive advantages can be gained there are also some obstacles named by the different authors: a lack of information regarding potential partners can lead to a greater degree of uncertainty; a collaboration leads to a dependency on partners; difficulties in decision making due to differences in priorities of partners and a loss of control of resources and related decisions (Baas & Boons, 2004). Also to realize co-operative concepts, the investment cycles of the partner companies as well as their organizational structures have to be brought in line. Further do Fichtner et al. also name energy specific obstacles like legal frameworks, administrative barriers and public opposition.

In this chapter inter-firm networks are covered. There are a lot of different forms of inter-firm networks. The first sections summarize the findings about two inter-firm networks that show similarities with the multi-user warehouse project. Two specific types of inter-firm networks are reviewed, eco-industrial parks and freight villages. These types of inter-firm networks were found during a first exploratory search on inter-firm networks with a link to sustainability. Both inter-firm networks have in common that they are formed from an economic as well as an ecologic point of view. Thereby do both networks have a link with logistics. The new Kuehne + Nagel warehouse project also has these characteristics. This is the reason to choose these specific networks for the study on inter-firm networks. In this analysis firstly an explanation of the network is given. Thereafter the success factors and limitations are reviewed.

In section 5.3 a comparison is made between EIPs, freight villages and the new Kuehne + Nagel warehouse. The success factors and limitations from the two inter-firm networks are assessed to see whether they also apply to the parties in the Madagascar project. As most of the literature reviewed name stakeholder management or engagement and organizational/governance structure as important success factors section 5.4 contains a stakeholder analysis.

5.1 Eco-industrial parks

Definition

At the end of the 20th century there was a shift in mindset. The view of ecology being a natural enemy of economy shifted to one where ecology could create and stimulate business. In the Netherlands the government tried to stimulate this thought with an Economy&Environment policy. One of the fields for action was sustainable business sites. It was defined as "*a form of cooperation between firms, and between firms and governments, aiming at the improvement of the economic performance of firms, the reduction of environmental pressure and a more efficient use of space"* (Pellenbarg, 2002).

In the years that followed, the principle of sustainable business sites evolved to sites where businesses also attuned and combined production processes. On these sites the industrial development was focused on improving the management of natural resources. In the literature there are various terms used for industrial developments focused around environmental management. Terms that are used are: eco-industrial networks (EIN), eco-industrial park (EIP), eco-industrial development (EID), networked/integrated eco-industrial parks, industrial ecosystems and industrial symbiosis (Tudor, Adam, & Bates, 2007). In this thesis the term EIP is used to talk about the clustering of businesses to achieve primarily environmental, but also social and economic benefits. An EIP is a community of businesses that seeks a collective benefit that is greater than the sum of the individual benefits. These benefits are accomplished by collaborating in the management of environmental and reuse issues for example by optimal circulation of materials and energy. EIPs have three main principles: (1) the minimization of energy requirement, (2) the use of industrial wastes as inputs and (3) the development of a diverse and resilient system(Tudor, Adam, & Bates, 2007).

Success factors and limitations

In the literature there are many success and limiting factors described for EIP development. A literature review was done by Sakr, Baas, El-Haggar, & Huisingh (2011) and Tudor, Adam, & Bates (2007). The literature review of Sakr et al. is used as basis because the authors give a categorized and clear overview. Furtheron this overview is complemented with factors named by Tudor et al. as well as the articles of Roberts (2004) and Pellenbarg (2002). This overview is shown in

	Success factors	Limiting factors
Symbiotic business relationships	• Establishment of the essential 'symbiotic' exchange relationships between the companies participating in the project. • Collaboration and formation of business networks. • The active participation and empowerment of stakeholders. • Champions functioning as a communication platform between the companies themselves and provides company management and staff with important ''social'' contacts. • Existing social networks may help to encourage environmental networking through forming mutual trust. • Trust in the competence of other companies. • Goodwill of other companies.	• To think that 'physical' energy, water, materials and by-product exchanges are the most important features of EIP development. • Lack of company interest. • Cooperation between companies cannot be mandated by the government. • Lack of stakeholders' involvement. • Absence of a champion. • Absence of trust in new dependency links.
Added economic value	• Involved parties gain an added economical value. • Willing to invest time, money and other resources in the development of an EIP.	• An exchange might be economically unsound or economically risky from a company perspective. • Lack of finance. • Costs of EIP planning are solely carried by the government.
Awareness & information sharing	• In order to stimulate development, it is important to focus on the establishment of low cost, high benefit utility sharing projects and "simple" exchanges. • Educate and inform companies of the potential benefits that can be achieved through the establishment of an EIP. • Effective structures for continuous technical assistance. • Transparent and efficient information exchange system.	• Unawareness of EIP principles and benefits. • Failure of companies to become engaged in the EIP even after participating in the awareness campaigns. • The right people do not have the needed information at the right time.
Policy & regulatory framework	• Policy intervention plays an enabling/catalyzing role in helping to identify opportunities and creating the appropriate condition for inter-firm networking to take place. • Stringent environmental laws that are effectively monitored and enforced by governmental agencies.	• Too much direct involvement from the government promoting an unattractive agenda from the companies' perspective. • Existing regulations do not support EIP principles.
Organizational & institutional setups	• Bilateral exchanges fit within corporate organizational structure and overall management system of the park. • Highly cooperative organizational culture in the area. • Well established Corporate Social Responsibility (CSR) or similar systems (i.e. EMS).	• The intended exchange might not fit in the current corporate organizational structure. • Behavioral resistance toward cooperation across organizations. • Perceiving collaboration as risky for competitive relationships • Limited decision-making powers.
Technical factors	• Already some energy, waste and materials exchanges exist among various companies. • Utilizing local technical-know-how.	• Absence of internationally accepted EIP standard
Balance between Capabilities	• There is a balance of emphasis upon different capabilities: Such as economic, values, technical, political, unlearning.	• Dominance of one type of capability.

Table 5 Success and limiting factors for EIP development
(after Sakr, Baas, El-Haggar, & Huisingh (2011), Tudor, Adam, & Bates(2007), Pellenbarg (2002), Roberts (2004))

5.2 Freight villages

Definition

The trend of global procurement and distribution of goods leads to changing logistical requirements. A competitive logistic infrastructure that can provide operational effectiveness within a network is therefore essential for firms to handle increasing complexity and ensure flexibility. Best practices from different industries indicate the need to implement efficient multimodal transition points and transportation links appropriately to establish powerful logistic systems. Modes are for example ships, trains or trucks (Winkler & Seebacher, 2011).

In this capacity, freight villages (FVs) can contribute to the development of a well-established and high-performing logistic network. A FV is a cluster of quality industrial-intermodal-distribution-logistics buildings on a distinct terrain. In this area also a range of support services are provided by every user. Those services are for example transhipment, handling and administrative operations (Tsamboulas & Kapros, 2003). It enables a high degree of accessibility and transfer freight from one mode to another (Wu & Haasis, 2013).

FVs can generate substantial benefits such as supply chain efficiency, intensive provision of logistics services, modal shift, regional economic growth and employment. Also environmental advantages and lower energy consumption can be achieved via FVs. These advantages can be realized by freight consolidation, transport companies' collaboration, urban transport route optimization and the usage of energy-efficient modes. The economic benefits are reached via reduction of operative costs by combination of logistics services, increase income by value-added services, enabling efficient management of the supply chain and maintaining long-term competitiveness for settled companies by cooperation.

Success factors and limitations

The success factors and limitations named by the different authors are ranging. A subdivision is used to make the overview more comprehensible. An overlap can also be seen with the factors influencing the success of EIPs. In this case only success factors are named and limitations would be the absence of those success factors. The success factors are displayed in Table 6.

	Success factors
Added economic value	• Involved parties gain an added economical value/ long-term competitiveness.
Knowledge management & information sharing	• FV companies should be connected to each other using appropriate information and communication systems to ensure the full transparency of the logistics processes. • The usage of appropriate technologies (barcode, track-and-tracing and/or EDI systems) contribute to synchronized information flow. • The composition of a knowledge management strategy. • Effective knowledge sharing between FVs and Ministry of transport is crucial for establishing an efficient traffic network.
Policy & regulatory framework	• The involvement of both public and private actors. • Involvement of governments and local authorities. • Stakeholder engagement.
Organizational & institutional setups	• Comprehensive and very well coordinated management. • Management activities must increase (goal-oriented) synergy for the companies involved. This should lead to greater efficiency and lower cost due to improved logistical performance. • A higher level authority coordinating logistical and supporting services on site while moderating the differing and conflicting interests. • The usage of logistics practitioners.
Technical factors	• A well positioned logistical infrastructure within a logistical network. • Adequate supporting services, productive equipment and sufficient space.

Table 6 Success factors for freight village development (after Wu & Haasis (2011), Wu & Haasis (2013), Winkler & Seebacher (2011), Tsamboulas & Dimitropoulos (1999), Tsamboulas & Kapros (2003))

5.3 Applied success factors and limitations

Both EIPs and freight villages are multi party projects that are utility based, just like the new Kuehne + Nagel warehouse. Also both inter-firm networks have a link with logistics and try to use the inter-firm concept to benefit in an ecological and economical way. Therefore the success factors and limitations named by the different authors are analyzed and the ones applicable to the Madagascar projects are summarized in this section.

Both literature reviews show that it is very important for inter-firm networks that all parties involved should benefit in some way. This could be in a direct, such as a saving in their business process, or in an indirect way such as better long term competitiveness. To get to these direct or indirect benefits a form of trust is needed between the participating parties and in the fact that long term relationships will hold and pay off. Besides trust there also should be the willingness to invest time and money to make the inter-firm project a success.

Communication is pointed out as another critical success factor. Sakr et al. elaborate on the role of a champion figure that should function as communication platform between the parties involved and an information system to support transparency. Wu & Haasis have knowledge management as main topic in both their papers and stretch its importance. The success factors that they name though are not very relevant because they are very much focused on the bundling of logistics. This could be interesting for the new Kuehne + Nagel warehouse during the operational phase but is not interesting for the sustainable projects during the development phase of the warehouse like a wind turbine.

For all inter-firm networks the importance of the government seems not to be underestimated. It plays an enabling and catalyzing role. Funding, investments, environmental law and permits are all important to the Madagascar projects and therefore an early involvement of the government and public authorities is definitely a success factor.

On the role of management of both forms also a lot is written. This management should be an autonomous organizational structure that should increase synergy and moderate conflicting interests.

Last but not least is the number of times that the before mentioned literature name stakeholders, stakeholder management and stakeholder engagement as important success factor. Therefore, together with the value of interests, a stakeholder analysis of the new Kuehne + Nagel warehouse project is given in section 5.4.

5.4 Stakeholder analysis

In the articles about eco-industrial parks and freight villages, stakeholder management was often mentioned as success factor. Wu & Haasis say that “the long-term survival and success of the corporation requires multi-stakeholder participation and support”. For this reason and also because recommendations can more easily been given if all stakeholders are identified, a stakeholder analysis is conducted.

According to Freeman’s classic definition: "A stakeholder in an organization is (by definition) any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman, 1984). In this research the organization that is talked about in Freeman’s definition is the new Kuehne + Nagel warehouse and even more specific the collaboration between parties to realize the sustainability options. The identified relevant stakeholders are summerized in Table 7.

Besides the identification of the different groups and individual stakeholders it is important to know their intersts. Freeman also argued that the central challenge of strategic management is to create a satisfactory balance of intersts among the diverse constiuencies that contribute to, or place something at risk, in the running of a business (Freeman, 1984). As was mentioned in the previous section the willingness to invest time and money is essential, but knowing why stakeholders want to invest time and money is even more interesting. With this information negotiations and discussions can be kept to a minimum and the viability of a project can be estimated in advance and enlarged (Post, Preston, & Sachs, 2002).

To identify the different interests of the stakeholders the stakeholder theory is used. In this model a clear distinction is made between the different groups and their interests. These interests were gathered from interviews and literature (Bergek, Mignon, & Sundberg, 2013) These interests should be translated into one clear organizational objective. The translation process can make clear if the project is viable and where trade offs should be made between interests (Jensen, 2001).

Groups	Stakeholders	Interest
Located companies	Unilver and warehouse clients of the new Kuehne + Nagel warehouse	Getting their products to their customers in a cost efficient and sustainable way
Logistics service provider	Kuehne + Nagel	Organize logistics from its clients in the most (cost) efficient way
Developer	WDP	Developing and leasing logistic and semi-industrial real estate that meet the requirements of their clients
Public authorities	Municipality of Tiel County of Gelderland, Water authoritiy (waterschap) Rivierenland	Guarding the public domain while developing an applealing business climate
Possible investors	Energy supplier, bank	Investing money in save and profitable (sustainable) funds
Surrounding civil society	Employees and residents	Having a save and pleasant place to work/live
Surrounding industry	Companies located at industry park Medel	Looking for possibilities for synergy

Table 7 Relevant stakeholders

Summary

In chapter 4 we argued that to realize a wind turbine and PV-panels inter-firm collaboration is required. In this chapter two specific forms of inter-firm collaboration were reviewed, *eco-industrial parks* and *Freight villages*. Both eco-industrial parks and freight villages are multi party projects that are utility based, just like the new Kuehne + Nagel warehouse. Also both inter-firm networks have a link with logistics and try to use the inter-firm concept to benefit in an ecological and economical way. For those two inter-firm collaborations success factors were reviewed that are also applicable and enlarge the success of the warehouse.

From the review of Eco-industrial parks and freight village literature the following *success factors* were selected for the new Kuehne + Nagel warehouse projects:

- All parties involved should benefit in a direct or indirect way
- A form of trust is needed between participating parties
- The participating parties should have a willingness to invest time and/or money
- A champion figure and information system should function as a communication platform between participating parties, especially during the development phase
- The government and public authorities should be involved in an early stage of the project for investments, permits, funding and environmental law
- Management of an inter-firm collaboration should have an autonomous organizational structure that should increase synergy and moderate conflicting interests
- Stakeholders should be managed and stakeholder engagement should be guaranteed in the project

Since stakeholders are very important in these collaborations also a stakeholder analysis was performed for the new Kuehne + Nagel warehouse. This stakeholder analysis is shown in Table 7.

6 Inter-firm project investment

As was concluded in chapter four some options that were not integrated in the building needed further research on a possible inter-firm project investment. These options are PV-panels with an investment sum of around € 225.000 and a wind turbine which has an estimated cost of € 1.1 million. In this chapter project finance is described. This is done from both a theoretical as well as a practical point of view. For the theoretical information literature on project finance is reviewed. Not all characteristics of project finance do apply to the new Kuehne + Nagel warehouse projects, namely the investment sum which applies as minimum in the literature is 20-30 million. Nevertheless the other characteristics are very similar and the benefits of project finance in multi party constructions are worth investigating. The literature review should provide an understanding of which factors are important for the new warehouse. In this case stakeholders, risks, capital and organizational structure are covered. To also bring in information from experiences with project finance two case studies are added. Those cases are all forms of project finance with a sustainability background.

In the last section the theoretical and practical information is assessed for the new Kuehne + Nagel warehouse project and guidelines for the application of project finance are described.

6.1 Theory on project finance

Project finance

In general, projects have some distinctive characteristics like singularity, a defined start and ending and a special purpose. The PV-panels and wind turbine are sustainable solutions that can be considered as projects since they satisfy those characteristics. These sustainable options are one-off solutions that have the special purpose of providing sustainable energy to the new Kuehne + Nagel warehouse. Both PV-panels and wind turbines have a limited lifetime during which cash flows can be generated.

To finance such projects, project finance can be used instead of the classic asset-based finance or corporate finance. Asset-based finance, which is a form of corporate finance, uses a pledge like premises to secure the invested money and interest will be paid from normal business of the borrowing company. In general corporate finance is based on the credit quality and profitability of a business. Project finance is based on the expected cash flows and earnings of the project as the source of funds from which a loan will be repaid. This points out one of the characteristics of project finance namely that finance is based on expected cash flows and the fact that the lender of the money cannot use the assets of the project without exploitation rights or off-take contracts. These long term agreements like off-take contracts but also insurances, supply contracts and construction contracts are also a characteristic of project finance. Other characteristics are the fact that a specific economic unity is formed where multiple parties share the risks of the project. From the sponsor perspective, which are parties contributing to the equity part of the project company, off balance sheet financing is possible. This means that the assets of the project are not on the balance sheet of the sponsor, only features of the financing will likely appear in footnotes depending on the project structure. The last characteristic and probably the most critical function of project finance is to reduce the investor's risk and exposure to liabilities. The investor's risk and exposure is reduced by sharing the costs of the project but also by the non or limited recourse element to sponsors. Non-recourse means that the sponsor is only liable for the resources invested, not for other parts of the business, in the event of failure (Yescombe, 2002).

Besides the fact that participating parties are only liable for their investment in the project there are other benefits of project finance. Those benefits are the fact that the parent company can concentrate on its core business and the investment can be off balance so it does not influence the financial ratios of the parent company. In addition project finance can be used to realize fiscal or tax advantages by using the optimal capital and organizational structure for the project.

Besides all the advantages mentioned there are also disadvantages in project finance. One of those disadvantages is the high costs for setting up the project organization and realize a capital structure that is agreed upon by all participating parties. Also the higher cost of capital is unfavorable. This higher interest rate is due to the fact that finance is based on uncertain cash flows instead of corporate profit and it is not pledged with assets from a corporation. To get external finance, lenders can also ask for more information than the initiators were intended to share. There are also higher administrative costs involved in project finance since diverse project studies (amongst others risk and sensitivity analysis) have to be performed. Moreover, the contracts between participating parties are also very costly due to their number and involvement of external experts like lawyers.

In case of the PV-panels and wind turbine projects for the new Kuehne + Nagel warehouse project finance seems like a suitable form. The new Kuehne + Nagel warehouse is a multiuser warehouse where project finance provides the opportunity for those parties to invest in sustainability. Projects financed jointly by different firms can help to avoid the problem that investments in such units often do not meet the pay-off times of one to three years required by many industrial companies. This is especially true if an inter-firm concept is realized as a contracting project, offering the possibility to shift financing issues, several project risks and possibly operation issues to a third party with specific know-how in this area, e.g. an electric utility (Fichtner et al., 2004). Besides the inter-firm concept also the non-recourse element of project finance is an advantage for participating companies. The participating companies or sponsors are only liable for the money invested in the project. The sponsors can also use the off-balance finance principle to distinguish this project from their normal business activities (Walter & Smith, 1998).

For project finance the cash flow as source for debt-service is crucial. In case of the PV-panels and wind turbine the expected cash flow will come from sold generated electricity. The electricity can be used to provide the new Kuehne + Nagel warehouse as well as others or it can be redelivered to the grid. The project will be managed by the project company, which is a special purpose company (SPC). This special purpose company (SPC) can serve as the specific economic unity mentioned earlier.

To clarify the principle of project finance, the different roles are explained. The overview of all actors and their roles is shown in Figure 12.

Investor/sponsors	The group taking the initiative for the project and contributing to the equity part by investing.
Lenders/Financers	The group of debt providers, they receive interest on their investment. This group of financers mostly consists of banks, government or institutional investors.
Project company	The special purpose company in which sponsors and other financers put together their money. The project company is responsible for managing the project.
Operator	The company that takes care of the generation of income after finishing the construction phase of the project. This role is mostly taken by the project company.
Government or public-sector authority	The public authority is responsible for building permits and legislation. This group can also be financer, risk hedging party and promoter for the project.
Offtaker	The future consumer of the project or project's output. To reduce the uncertainty for the project, agreements about the off take are made.
Input supplier	The supplier of any raw material for the project. Also with this group contracts are made to reduce the uncertainty for the project.
Contractor	The company that is responsible for the construction of the project. This actor can also be one of the sponsors of the project.

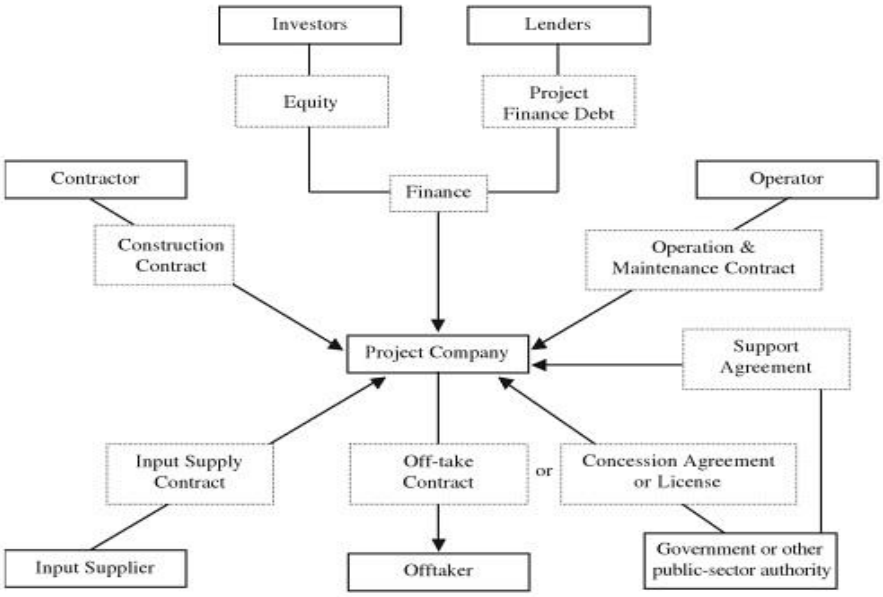


Figure 12 Project finance structure (Yescombe, 2002)

Risks

In the literature on project finance there are several types of risks distinguished. The risks mention hereafter are from (Smith, Walter, & DeLong, 2012) these risks correspond with risks named by other authors like (Grimsey & Lewis, 2002) (Nikolic, Jednak, Benkovic, & Poznanic, 2011) and (Farrell, 2003).

Resource risk involves the risk that the required resources, basis for debt service are not present in the required quality or quantity.

Input or throughput risk concerns the risk of the project depending on the availability and price of raw materials or other resources needed for the operational phase of the project.

Technical risk relates to the engineering characteristics of the project itself.

Timing risk focuses on the possibility of delays and the costs involved in these delays.

Market risk concerns future demand and prices for the product or service supplied by a given project.

Operating risk focuses on the long period of time that projects and their financing generally involves. During this long period costs may change or labor, transportation, or other critical element may be disrupted by external sources or management incompetence. Other operating problems include the inability to meet output targets or quality specifications, high maintenance and other factors. Location, stability of the local labor pool and proven track record under similar circumstances of the project constructor and operator are the best predictor of this type of risk.

*Force majeure risk*s are nature-related calamities and other uncontrollable events that may lead to failure, destruction or disruption. Provisions to accept force majeure risk are usually agreed by lenders also insurances could be used.

Political risk involves the political conditions that surround a project during the period covered by a financing. This risk includes tax changes, newly imposed environmental controls, licenses, permits and legal changes.

Most of these risks have a financial impact. This impact can be reduced via contracts (supply, take-off and construction) and insurances. Distinction in insurances can be made between insurances during the construction period (construction all risks (CAR) and liability) and the operational period (machinery breakdown, business interruption etc.). Besides appropriate insurances and contracts also the financing form of the project is important for project finance and the parties involved.

An important part of the successful closing of a project financing is the risk structuring process. It is during this process that risks are identified, analyzed, quantified, mitigated, and allocated. This is done so that no individual risk threatens the development, construction, or operation of the project in such a way that the project is unable to generate sufficient revenues to repay the project debt, pay operating expenses, and provide an attractive equity return to investors. To allocate and mitigate risks a risk matrix can be used. In the risk matrix the identified risks are allocated to one of the actors in the project, this is the actor is able to control the risk best or influence its outcome. For this risk compensation is

demanded by this actor. This mitigation can also be in the form of insurances or guarantees. These mitigations are displayed in a mitigation column of the matrix. Moreover the matrix also shows the effect of the risks on lenders and developers in a separate column. With this matrix risks are managed, responsibilities are made clear and possible effects are shown (Hoffman, 2007).

Capital structure and financing aspects

Capital structure refers to the way a corporation finances its assets through some combination of equity and debt. In project finance there does not appear to be an optimal capital structure. However, equity usually comprises 20%-40% of overall capitalization. The capital structure with a minimum amount of equity should give lenders signs that there is commitment for and confidence in the project. Investors are balancing the capital structure in such a way that risk is minimized by limiting equity contribution and on the other hand maximizing profits/dividends (Walter & Smith, 1998).

The higher the debt/equity ratio, the more costly the financing is likely to be, and the more security there should be provided for lenders. The fact that debt is more costly appears in a demand for higher interest rates or more strict guarantees given by the sponsors. Other financial aspects that are related to the capital structure and that have to be agreed upon are: the duration of the loans, the use of derivatives and the origin of loans (export credit and multilateral sources of finance).

The capital structure is additionally influenced by the amount of subsidy that is available for the project. In the case of sustainable sources of energy most developed countries have some sort of stimulating arrangements or funds. Besides subsidy the local government is also important for project finance regarding tax. Deciding which capital structure suits best is also depending on the tax regulations of the country.

Organizational structure

Up till now the stakeholders and their roles, risks and capital structure were discussed. One of the stakeholders is the special purpose company or project company. To organize the different parties and minimize risks, a suitable organizational structure for this project company is important. There are multiple sorts of organizational forms with different attributes. The main organizational forms are sole proprietorship, partnerships, corporations and cooperatives. Under these main organizational forms are a lot of possible sub forms. The attributes on which these forms differ are the number of owners, ease of startup, investor liability, equity capital sources, firm life and liquidity of ownership and taxation (Leach & Melicher, 2006).

The characteristics of project finance and the benefits of a special purpose company exclude already two of the main organizational forms, proprietorship and partnerships. Both of those forms are distinguished by the fact that investors' liability is unlimited. In proprietorship the singular owner is not only liable for the money invested in the business bus also for its personal belongings. In a partnership (general or limited) there are one or more general partners who are, like in a proprietorship, fully liable. Corporations and cooperatives are legal entities that are separated from the owners and shareholders. Shareholders of these entities are not personally liable for the debts, obligations or acts of the entity.

In the literature about project finance many sub forms of corporations and cooperatives are named. Walter & Smith mention nominee corporations, jointly owned corporations, joint ventures and trusts. Multiple legal forms can be combined in the organizational structure. Also the forms in which governement and public authorities invest are common in the literature (Tang, Shen, & Cheng, 2010). Acronyms as BOT (Build-Operate-Transfer), BOO (Build-Own-Operate), etc. are named as possible forms of project finance as well. What most authors conclude is that the organizational structure should follow the capital structure, legal conditions, minimize risk and enable benefits in taxation. Thorough legal knowledge of the country where the project takes place is crucial is needed to come to a sound decision.

6.2 Practical examples

Northwind

Northwind is an offshore wind farm that is currently being constructed on the Bank Zonder Naam (Lodewijkbank) off the coast of Zeebrugge in Belgium. This wind farm will consist of 72 wind turbines with a total capacity of 216 MW. The expected annual production of the farm is 0.875 Terrawatthour, this equals the energy requirement of 230,000 Belgian households. Development of the park started a while ago and should be operational in 2014. Typical phases in this process are: concession, development, construction, operation. Northwind is currently in the construction phase. For this thesis we are mainly interested in the financial structure and experiences from shareholders.

About 70% of the project will be financed by banks and 30% by private investors. Two of the main private investors are the Belgian green energy company Aspiravi Offshore owned by 95 municipalities, and the project partner Parkwind, which is the Belgian retail group Colruyt's wind energy vehicle. There will also be additional financial investments from the investment company Gimv, the Colruyt family and the Participatiemaatschappij Vlaanderen (PMV). The European Investment Bank will extend a 335-million euro loan for the project, while Northwind has signed a 15-year contract with Electrabel for the electricity supply.

The project financing is based on a non resource construction where project debt and equity used to finance the project are paid back from the cash flow generated by the project. Non resource means that the lending bank is only entitled to repayment from the profits of the project, which the loan is funding, not from other assets of the borrower. These types of projects are characterized by high capital expenditures, long loan periods, and uncertain revenue streams. The complete financial structure is shown by Figure 13.

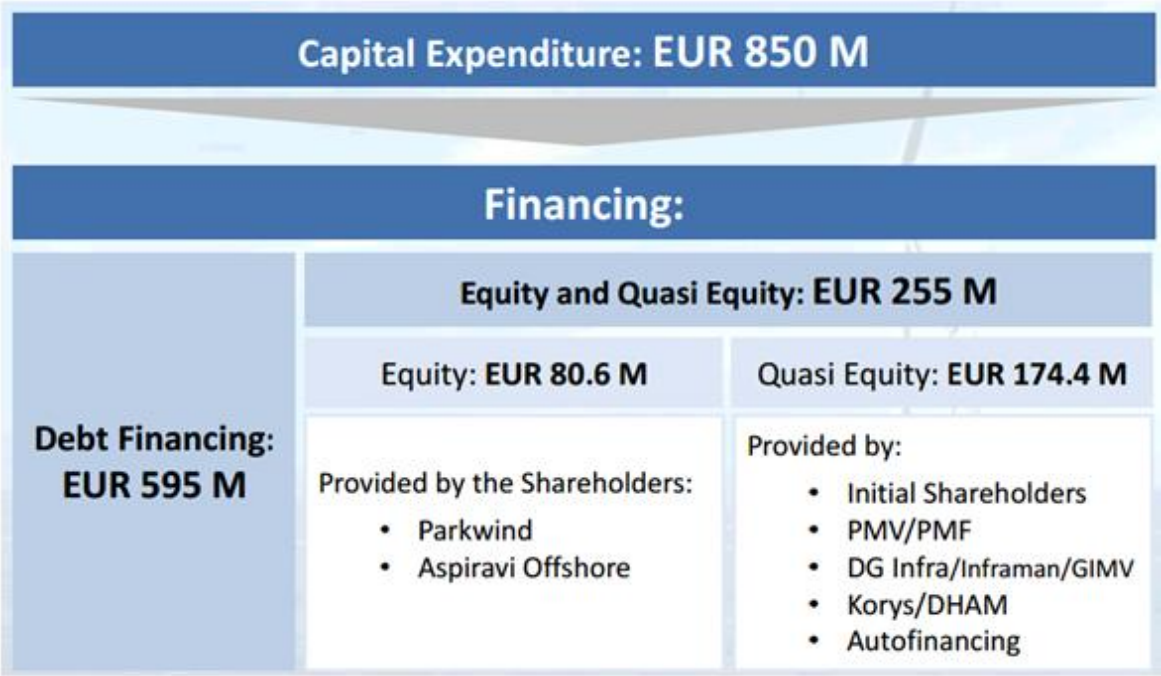


Figure 13 Financial structure Northwind project (Northwind, 2012)

For the Colruyt Group it is the second large wind farm they invest in. About 3 years ago the Belwind wind farm was also constructed with financial recourses from amongst others the large Belgium retailer. The mission of the Colruyt group is 'together, we create sustainable added value by value-driven expertise in retail'. The sustainable part of this mission is amongst others evident in the solar panels on numerous of their more than 200 retail shops. But for the Colruyt group this was not enough. Their vision is that more has to be done to create a sustainable world and to be innovative you have to take risk and sometimes accept a lower profit. The experience from Belwind is used for Northwind and there are already ideas to develop a third wind farm: Belwind 2.

Risks and valuable lessons learned in the two wind park projects that were mentioned by the Colruyt group are:

- Regulations. There is a lot of regulation concerning such large and sustainable projects. Being familiar with these regulations is very important to develop a viable project.
- Financial risk management. It was a well-thought decision to have multiple parties participating in the project. On the one hand to diverse the risk and on the other hand because of the size of the investment. Risk management is also important because of the fluctuating energy price.
- Experience in contract management. Valuable lessons were learned about procurement of wind turbines and sales contracts for energy generated.

Success factors according to Colruyt were a very strong and diverse project management team and a consensus culture between stakeholders. This latter means that there were open discussions and alignment in decision making rather than voting.

EMU-Energy/ Unilever DC Heilbronn

Unilever has a distribution centre in Heilbronn (also used as factory warehouse for their sourcing unit Heilbronn which produces food products). To make this distribution centre more sustainable solar panels could provide a part of the needed power for the distribution centre. Technical calculations made clear that this project would have a payback period of around 10 years. This payback period is too long for Unilever projects which have a standard payback period of less than 3/4 years. This is why the warehouse employees of Unilever started an initiative. In 2010 472 photovoltaic panels were installed on the roof of the high rise part of the warehouse financed by employees from site Heilbronn (Figure 14) (warehouse, factory, R&D and Foodsolutions).

The total costs of the project were around €360,000 of which €125,000 Euro is equity and a loan of €235,000 from two banks. The equity part of the financial construction consists of 415 shares of €300 that are owned by 57 employees, united in the cooperative called 'Energiegenossenschaft Mitarbeiter Unilever (EMU)'. The partitioning of 1/3 equity and 2/3 loan was chosen because of its favourable interest rate for shareholders. The banks that invested the money were a governmental bank and a cooperative bank. The fact that these banks had the same interests and cooperative structure made the negotiations easier.

EMU is a cooperative, which is a cheap and easy form of business to start and members are only liable to the limit of their investment. Also the fact that counselling/accounting for a cooperative is not very expensive in Germany was reason to choose for this structure. The form of the cooperation is based on the principle of many agricultural firms. Contractually it is defined how parties get in or out of the cooperation, who is the steering and controlling organ.

Figure 14 PV panels on the roof of the Unilever DC in Heilbronn (EMU, 2013)

Problems that were encountered in the process of starting up the project were:

- Risks that should be covered like fire hazard, this was covered with an insurance and a lot of consultation of the fire brigade to keep the risk to a minimum.
- Renting the roof. For tax reasons it was not possible to let the project use the roof for free. Therefore the project pays rent and this is returned in the form of a Unilever sponsorship.
- An exit strategy is needed if Unilever sells the warehouse and the new owner does not want the power plant on the roof. In this case Unilever will cover the residuary expected turnovers for the stakeholders.
- The bank needed a pledge for the loan; this was against normal Unilever standards but was accepted this time.

Crucial was the buy in of senior management for example for using the roof, have legal support and using the name of Unilever.

Also another green energy source was considered, this was a wind turbine. The fact that this option was not chosen is that Heilbronn isn't an ideal location for wind energy, biologists should investigate the effect on species, and wind turbines are more expensive and are mostly build in larger numbers at the same time.

6.3 Financing the sustainability projects of the new warehouse

In this chapter theory about project finance and examples from practice were studied. In this section the findings from those studies are applied on the PV-panels and a wind turbine for the new Kuehne + Nagel warehouse. Both projects are very small investments from a project finance perspective, respectively €225,000 and €1.1 million against €20-30 million. Nevertheless this way of financing seems to be a good option as long as the benefits are larger than the costs of setting up an appropriate capital and organizational structure. In this form of finance it is possible to invest in sustainability without risking the core business of the sponsors.

Stakeholders

In section 5.4 the stakeholders of the new Kuehne + Nagel warehouse were named. With the information of this chapter the possible roles for those stakeholders are named. The developer, Kuehne + Nagel, Unilever and other clients of the warehouse are all possible sponsors. From information of the case study of Heilbronn we conclude that also the employees of the warehouse or of one of the clients can be sponsors. Another option for raising equity can be crowd funding which is a relatively new form of financing. Since Unilever and Kuehne + Nagel have the will to collaborate to realize sustainability they are most appropriate parties to initiate the projects. Kuehne + Nagel will also be the main off-taker for both projects. By giving guarantees for a minimum off take of electricity K+N can make the projects viable.

Possible lenders are banks, the government or other public authorities. Both types of projects qualify for funding via the so called EIA arrangement (Energieinvesteringsaftrek regeling), which is public funding. Besides this subsidy the government is also a potential investor for both projects. Banks in the

Netherlands that are well known for their investments in sustainable projects are the Triodos Bank and the ASN Bank. One of those banks could also take the role of lead bank and make the sensitivity and risk analysis.

The government and public authorities are also important to involve in the project because of their decision making power about permits and development plans of a region. Both projects need permission and early involvement of the local authorities can save a lot of trouble and effort.

Risks

The forms of project finance risks named by Smith et al. were depicted in section 6.1. In this section the probability of these risks for the Kuehne + Nagel warehouse sustainable project options (PV-panels and a wind turbine) are described.

Resource risk: For the Madagascar projects the required resources are sunlight and wind. Since PV-panels and wind turbines are often used in the Netherlands and the availability of sun and wind is constant over years this risk is minimal for the sustainability projects.

Input or throughput risk: For wind turbines and PV-panels the only required input is wind or sun. This resource is freely available, so no price risk or risk of shortage can be expected.

Technical risk: The techniques used for PV-panels and wind turbines are not state of the art and already widely. Therefore the technical risk with these techniques may be considered very small.

Timing risk: For the sustainability projects there is a small chance for delay. This chance is mostly due to the fact that the date of a financial close is unsure and also permits have to be obtained.

Market risk: Looking at the possible projects for this warehouse market risk is one of the most probable risks. This is due to the volatility of energy prices. The business case is very depending on the expected price Kuehne + Nagel has to pay for energy and what the price will be if energy is sold or redelivered to the grid. Before these options are implemented a sensitivity analysis should be done by generating best-case, base-case and worst-case scenarios.

Operating risk: The new Kuehne + Nagel sustainable warehouse projects have an operating period of 30-40 years in which operating risk is present. Although this seems like a very long period the technique used are well known and widely used in the Netherlands which makes this risk not very likely. Also the fact that not much labor is needed reduces the operating risk because the importance of the local labor pool is minimum. The track record of constructor and operator are not known yet but recommended is to take these track records into account in choosing those actors preceding signing of the contracts. As described by Fichtner et al. the involvement of multiple parties can also reduce operating risk by using know how and expertise from those parties.

Force majeure risk: All projects are subject to this type of risk including the sustainability projects. This risk can partly be covered by insurance and for the remainder being accepted. This acceptance can be translated into the interest rate of lenders.

Political risk: The political environment in the Netherlands is not as stable as it used to be therefore there is a certain political risk. Also the fact that the municipality of Tiel has to agree on especially the wind turbine can be considered as risk.

Capital structure

From the theory described in section 6.1 and the practical examples of 6.2 an equity percentage of 20%-40% of the overall capitalization seems like a good estimator for the required equity in the new Kuehne + Nagel warehouse sustainability projects. This advice is bases on limited information but the information suggests that 20-40% is best suitable for this case. This percentage should give lenders the sign that there is confidence in the project and commitment from participating sponsors. On the other hand is with this percentage risk minimized while possible return on investment is maximized. To make the debt not to costly guarantees can be given on the off take of electricity by the warehouse clients. Important is also to involve the government because of stimulating arrangements and available funds. The government can be a lender with a low interest rate as well.

In the case of PV-panels the owner or leaseholder of the warehouse should be involved for making the roof available for those panels. Hiring of the roof can be part of the capital structure and rents should be paid by the special purpose company as was explained in the example of Heilbronn in section 6.2. Another important lesson from Heilbronn was the possibility of employee involvement. This created a source of investments as well as commitment from an important stakeholder in the new warehouse.

From the practical examples in section 6.2 is can be concluded that there are certain types of financial institutes that are willing to invest in sustainable projects. Those institutes are mostly public institutes or bank with a sustainable mission. In case of the Northwind project the European Investment Bank invested a large sum and also the Dutch bank ASN, which has a sustainable trademark, was involved. For the PV-panels in Heilbronn one governmental bank and one cooperative bank are lenders.

Organizational structure

For project finance a special purpose company has to be established. The special purpose company has to make sure that participating parties are only liable for their investments. Since a lot is still unknown about legal, fiscal, financial and political aspects relevant to the sustainability projects, not much can be said about the organizational structure of this special purpose company. The organizational structure should follow the capital structure and legal advice in the formation of this entity is recommended.

Suggestions for implementation

With all the information given above suggestions for implementation can be given for the two sustainability options of the new Kuehne + Nagel warehouse. To make sure no effort is wasted local authorities should agree to give permission for both options. Subsequently the form of finance should be chosen. If collaboration is desired project finance can be used, otherwise corporate finance by the developer or a public private partnership could be considered. For project finance sponsors and lenders should be found and brought together. These sponsors and lenders together negotiate for a suitable capital and organizational structure. Possible sponsors are WDP, K+N, Unilever, other warehouse clients and employees. Not all sponsors have to bring in cash, guarantees for electricity off take or possible

pledges for loans also make the project more interesting for lenders and thereby more viable. Lenders for these projects could be Triodos Bank and ASN Bank. Those lenders need a project plan including expected cash flows from the projects, this can be done with a sensitivity analysis. A risk matrix should be drawn up to define the risks, risks takers and mitigations for those risks.

Summary

A specific form of inter-firm collaboration is inter-firm project investment. To give recommendations about financing a wind turbine and PV-panels in a multiparty construction, project finance was studied. Project finance is based on the expected cash flows and earnings of the project as the source of funds from which a loan will be repaid. The characteristics found in both literature and practice are a special purpose company, non or limited recourse to the sponsors and distinction of the project from normal business activities of the sponsors. These are all advantages of project finance for the parties involved in the new Kuehne + Nagel warehouse. Large disadvantages are the higher costs of setting up project finance, the many contracts and the risks that should be shared between involved parties. The most important risks for the wind turbine and PV-panels are market risk, due to the volatility of energy prices, and political risk since the success of the project will most likely be dependent on grants and permits from the public sector. The possible capital and organizational structure with potential stakeholders (blue) are shown in Figure 15.

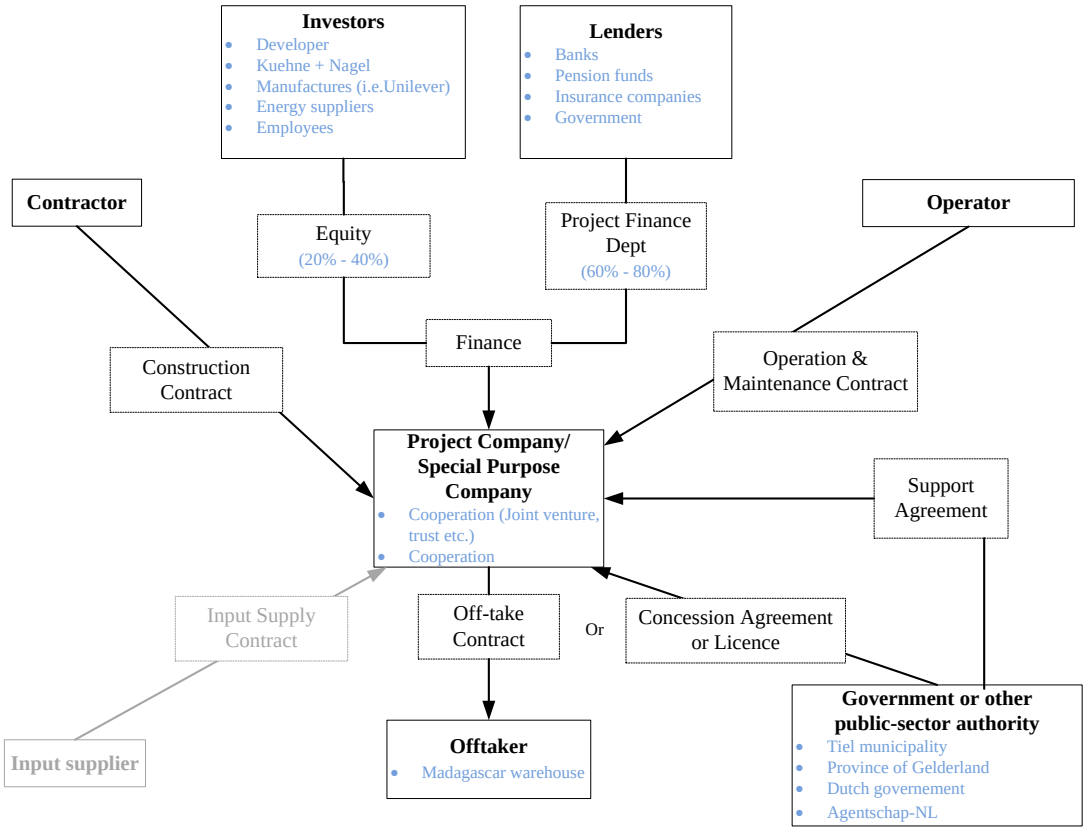


Figure 15 Possible capital and organizational structure with potential stakeholders

7 Conclusions and recommendations

This chapter gives answers to the research questions and provides recommendations for the development of a sustainable warehouse. The goals of this research were to find possible options to ensure a warehouse where sustainability meets performance and give insight in forms of collaboration between parties in a complex and multi-user projects to realize sustainability. Theoretical as well as practical research was used to answer the research questions and attain the research goals.

Conclusions

This research was initiated to find an answer to the research question:

How can the new Kuehne + Nagel warehouse in Tiel be built in a sustainable and cost efficient way and what organizational structures could be used between parties to realize complex sustainable options?

In order to get the answer to this research question six sub questions were formulated. During the research the different sub questions were answered. In this section the answers to those sub questions are summarized. Thereafter the research question is answered.

Sub question 1. What are options to build the new Kuehne + Nagel warehouse in a sustainable way?

In this research all kind of different options were gathered to make the new warehouse more sustainable. This research focused on the options that can be implemented during the building phase of the warehouse. The more than 40 options subject to this research fall in different functional areas such as heating, lighting, water, energy and waste. Most of the options are based on the principle of reducing the energy demand, but there were also options researched that could satisfy the remaining energy demand in a sustainable way.

Sub question 2. What are evaluation criteria for those options?

To give a deliberated recommendation about the possible sustainability options for the new Kuehne + Nagel warehouse the options were evaluated. To evaluate the options a multi-criteria analysis was used. The criteria for this analysis were composed together with a building expert from Kuehne + Nagel. The criteria were drafted on the basis of the Madagascar warehouse slogan ‘sustainability meets performance’. Furthermore the criteria were subdivided into MUSTS and WANTS. MUST criteria are obligatory characteristics that an option should have even to be considered for recommendation. WANT criteria are preferable characteristics that an option posses. The MUST criteria were:

- *Increase ecological sustainability or improve working environment*
- *Little negative impact on the operation*

The WANT criteria were:

- Improvement of the working environment
- Low effort for implementation
- Low Costs
- Increase ecological sustainability
- Increase marketable image
- Increase BREEAM score

Sub question 3. What options should be implemented based on the evaluation criteria?

Weights were allocated to the different evaluation criteria based on their importance. With a score on every criterion and a weight for each of those criteria a balanced score per option was generated. These final scores for each option resulted in a classification of 'Do' or 'Don't'. Besides these two classes there was also a 'Research' category. In this category there were options of which information was not sufficient to give a recommendation or the score was in between the 'Do' and 'Don't' category. For those options extra investigation was needed to be able to give a grounded advice. This extra research was in co-operation with a real estate agent CBRE. The 'Do' options from the multi-criteria analysis together with the ones from the extra research by CBRE are given in Table 8. Those options are recommended to be implemented in the new Kuehne + Nagel warehouse.

Insulation (Rc 3.5)	Determining most effective location of light sources
Thermographic assessment (inside out)	Windows (east and west side)
Thermographic assessment (outside in)	Intelligent lighting/motion sensors
Air curtains for loading docks	Fluorescent T5 lighting (high frequency and dynamic)
Humidity control	Motion sensors for taps and showers
Heat recovery from ventilation	Double flush systems and flush disruptors for toilets
Acoustic alarm for warehouse doors	Power consumption (sub)meters
Green façade	Stimulating waste segregation
Radiation heating + fans	Compressing/cracking of waste
Determination of required light levels	Origin of building material
PV-panels *	Ground heat pump + under floor heating
Wind turbine *	

Table 8 Recommended sustainability options for the new Kuehne + Nagel warehouse

In Table 8 there are also two sustainability options indicated with an asterisk. Those options came out positive from the CBRE research. For those options a high initial investment is needed and it could be seen as a distinct project within the new warehouse project separated from the building. To implement those options with multiple users from the warehouse more information is needed about inter-firm collaboration and specifically about inter-firm project investments.

Sub question 4. What are key success factors and limitations for sustainable inter-firm collaboration in a multi-user (horizontal as well as vertical) project?

To give an advice about inter-firm collaboration two different forms of inter-firm collaboration for sustainability in a logistics environment were reviewed. From the review of Eco-industrial parks and freight village literature the following *success factors* were selected for the new Kuehne + Nagel warehouse projects:

- All parties involved should benefit in a direct or indirect way
- A form of trust is needed between participating parties
- The participating parties should have a willingness to invest time and/or money
- A champion figure and information system should function as a communication platform between participating parties, especially during the development phase

- The government and public authorities should be involved in an early stage of the project for investments, permits, funding and environmental law
- Management of an inter-firm collaboration should have an autonomous organizational structure that should increase synergy and moderate conflicting interests
- Stakeholders should be managed and stakeholder engagement should be guaranteed in the project

Sub question 5. What capital and organizational structures could be used, for the sustainability options with high initial investments, in a multi-user project?

From project finance literature review and case studies it became clear that there are a lot of possibilities for financing a project. The sources used elaborate on the fact that a special purpose company can realize non or limited recourse to the sponsors of the project. A special purpose company also gives the possibility to make it a multi-user project. Besides this special purpose company it became clear that the organization structure should follow the capital structure of the project. The right organizational structure can also be used to gain tax benefits.

Both case studies had an equity percentage around 30% and literature is naming an ideal equity percentage of 20-40% for project finance. This capital structure achieves the highest return on investment for sponsors while it ensures lenders of debt that there is confidence in the project. The capital structure is complex structure through the large amount of possibilities in contracts, options and guarantees.

Sub question 6. Which structure suits the needs of the new Kuehne + Nagel warehouse best?

Project finance is based on the expected cash flows and earnings of the project as the source of funds from which a loan will be repaid. The PV-panels and a wind turbine for the new warehouse are a very small investment compared to normal project finance. Therefore lenders can request a high interest rate or are not interested at all in financing these projects. If this is the case a hybrid form can be used, in contrast to pure project finance, by using assets from one of the sponsors as pledge or guarantees can be given for example for the off take of electricity.

The organizational structure depends on the capital structure chosen and should be discussed by the project sponsors, lead bank and other lenders.

If a multi-party structure is chosen risk management is an important success factor. The risks that are important for the new Kuehne + Nagel sustainable warehouse project are market risk, operational risk, force majeure and political risk. To manage those risks a risk matrix can be a very helpful tool. In a risk matrix the risks, risks takers and mitigations for those risks are defined.

With the answers from the sub questions we are able to answer the main research question: **How can the new Kuehne + Nagel warehouse in Tiel be built in a sustainable and cost efficient way and what organizational structures could be used between parties to realize complex sustainable options?**

The options to build the new warehouse in a sustainable and cost efficient way that were derived from our decision analysis are summed up in Table 8. Those are the options that should in our opinion be included in the building preferences for the developer of the warehouse. The more complex

sustainability options, PV-panels and a wind turbine, can be realized using project finance. Based on the research a special purpose company is recommended for several reasons. The organizational and capital structure of this SPV are dependent of the involved parties.

Recommendations

In this last section the recommendations that are derived from this research are summarized. Thereafter directions for further research and the scalability of the recommendations are given. The recommendations should match the deliverables of the research. There are two deliverables for this research. The first one is a list of possible options and selection criteria to make Unilever's warehouse activities more sustainable. The second deliverable is guidelines for the process of project finance to realize large sustainable investments in a multiparty concept. These guidelines consist of project stakeholders, risks and success factors. Also directions for an organizational and capital structure are given. For these recommendations the same steps that could be identified in the research are used and it is specified for whom the recommendations are and how urgent or important they are.

Sustainability options: The recommended 'Do' options (Table 8) should be used by Kuehne + Nagel in the negotiations with the developer of the new warehouse. These options are important since they can reduce the energy demand by almost 50%. This reduction can save Kuehne as well as Unilever a lot of money spent on energy. The fact that the developer will have to implement the options is because all of these do options, except for PV-panels and a wind turbine, should be implemented during the construction phase. Kuehne + Nagel should also point out the advantages of the different options for the developer, like the increased chances to lease the building again after the contracts expire.

Inter-firm collaboration: The success factors and limitations which are derived from experiences with FVs and EIPs should be used by all parties involved in realizing the options that need inter-firm collaboration. All parties involved should benefit in a direct or indirect way. A condition to achieve this benefit is a willingness to invest time and/or money. Stakeholders should be involved and managed. One of the important stakeholders in projects like the sustainable energy for the warehouse is the government or public authority because of their influence on permits, funding, environmental law and possible investments. Creating synergy and moderate conflicting interests can best be done by an autonomous organizational structure. Not using these experiences from previous projects can result in a failing project or at least not maximizing the profits such a project offers.

Inter-firm project investment: From the findings of our research we recommend to use project finance for PV-panels and a wind turbine if the benefits surpass the costs of setting up an appropriate capital and organizational structure. A further financial analysis on sensitivity of those options regarding the price of energy is strongly recommended as contracts are based on these expected cash flows. Possible sponsors for those projects are manufacturers making use of the new Kuehne + Nagel warehouse but employees can also be considered as possible sponsors as was seen in Heilbronn. Possible stakeholder and a premeditation of the organizational structure are shown in Figure 15 (chapter 6). The most important risks for the wind turbine and PV-panels are market risk, due to the volatility of energy prices, and political risk since the success of the project will most likely be dependent on grants and permits from the public sector.

Further recommendations that were discovered during the execution phase of this research are also given.

- In the multi-criteria analysis one of the criteria was 'Increase marketable image'. The scores of the different options can be used by Unilever to make a selection which of the options should be highlighted in promotion material. This promotion material can be in diverse expressions like a movie, news article or brochures. The 'green façade' that is shown in Figure 16 is one of the examples that could be used as eye catcher for the building, if implemented. For the PV-panels and a wind turbine such visibility should be realized in another way, for example by a miniature, projection or canvas of the project in the lobby of the warehouse.

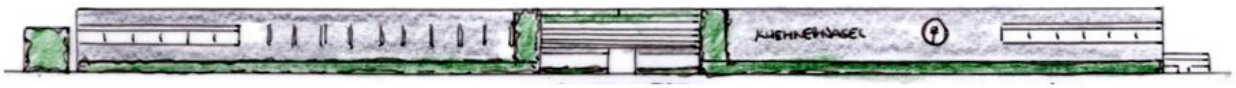


Figure 16 Front view with green façade (Copijn, 2013)

- This research is focused on sustainability options for the construction phase and the generation of sustainable energy. Besides these areas there are a lot of other possible areas for sustainability in warehousing, such as usage and maintenance of the warehouse and transport from and to the warehouse. Further research, by Kuehne + Nagel, Unilever and other manufactures in the new Kuehne + Nagel warehouse, is suggested to investigate possibilities and assess these possibilities. For this assessment most of the criteria used in the multi-criteria analysis can also be used.

In the literature on freight villages and eco-industrial parks synergy was often mentioned. A recommendation for further research is to find out what possible ways of synergy there exist or can be created around the Medel industrial park. This synergy can be focused on sustainability but there is also potential economic benefit. One of the forms of synergy from the research on freight villages is intermodal transport. Using inland waterways to transport goods can have economical as well as ecologic benefits.

During this research also options for storage of energy and specifically electricity were found. These options are not yet economically viable. For the future this is an area to monitor since it can have a large impact on the business case for a lot of sustainability options. This also applies for regulations for energy supply. If the regulations change concerning the electricity grid and redelivering to this grid the business case can change as well.

Further research is also needed in forms of finance whenever the sum of investment is under 20-30 million but inter-firm collaboration is desired. During this thesis it was experienced that not all the literature make a clear distinction in the size of an investment and effects of this different size on the capital and organizational structure. Since there is a trend in logistics towards more collaboration further research should be done to the possible forms of co-investment.

Another area of possible research is the combination of sustainability and firms' core business. During this research a lot of involved parties were skeptic about investing in sustainable business. There is a lot of research done about the positive effect of sustainability on the operating profit but from the researchers point of view there is a lack of explanation how to embed sustainability into the firms' core business. To achieve the sustainable targets from the European Union on sustainable energy production all the industries have to contribute.

For Unilever one important question is also whether or not these options can be used in other Unilever warehouses or warehouses used by Unilever. Most of these options can also be used in other warehouses. For this duplication of the options there are some areas of attention: the climate is of large influence on the effectiveness of options, the location and positioning of the warehouse is links also to the effectiveness and possibilities. These possibilities are related to the available infrastructure, other companies to collaborate with and also the political climate. Additionally it can be concluded that also the construction of ownership is very important for realizing sustainability options.

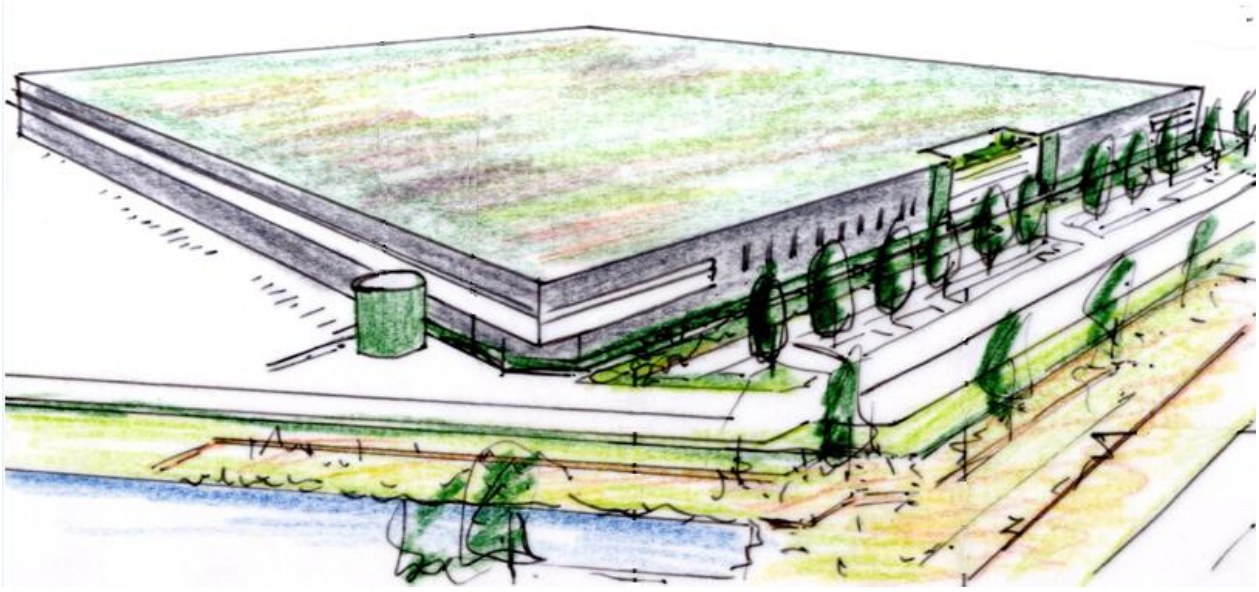


Figure 17 Possibilities for a green warehouse (Copijn, 2013)

Bibliography

Baas, L. W., & Boons, F. A. (2004). An industrial ecology project in practice: exploring the boundaries. *Journal of Cleaner Production* , 1073–1085.

Bergek, A., Mignon, I., & Sundberg, G. (2013). Who invests in renewable electricity production? Empirical evidence and suggestions for further research. *Energy Policy* , 568-581.

Brundtland, G. (1987). *Our Common Future.* Oxford: Oxford University Press; for the World Commission on Environment and Development.

Burek, S., & Habeb, A. (2007). Air flow and thermal efficiency characteristics in solarchimneys and Trombe Walls. *Energy and Buildings* , 128-135.

Copijn. (2013). *Studie naar zichtbaar maken duurzaamheid.*

Das, T. K., & Teng, B.-S. (2000). A Resource-Based Theory of Strategic Alliances. *Journal of Management* , 31-61.

de Boer, L. (1998). *Operations Research in Support of Purchasing.* Beta, Research School for Operations Managment and Logistics.

Dyer, J. H., & Singh, H. (1998). The relational view: cooperative strategy and sources of interoganizational competitive advantage. *Academy of Management Review* , 660-679.

EMU. (2013). *Photovoltaikanlage auf dem Dach des Hochregallagers in Heilbronn*. Retrieved June 11, 2013, from Energiegenossenschaft Mitarbeiter Unilever e.G.: http://www.emu-energie.de/index.php?cmd=bildergalerie

Farrell, F. M. (2003). Principal-agency risk in project finance. *International Journal of Project Management* , 547–561.

Fichtner, W., Frank, M., & Rentz, O. (2004). Inter-firm energy supply concepts: an option for cleaner energy production. *Journal of Cleaner Production* , 891-899.

Fieldson, R., & Siantonas, T. (2008). Comparing methodologies for carbon footprinting distribution centres. COBRA 2008.

Freeman, R. (1984). *Strategic management: A stakeholder approach.* Boston: Pitman.

Giulani, I. A. (2009). The design and development of an adaptable modular sustainable commercial building (Co2nserve) for multiple applications. *International Journal of Ventilation* , 123-133.

Glavic, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. *Journal of Cleaner Production* , 1875-1885.

Grimsey, D., & Lewis, M. K. (2002). Evaluating the risks of public private partnerships for infrastructure projects. *International Journal of Project Management* , 107-118.

Han, H. J. (2010). New developments in illumination heating and colling technoliges for energy-effiecient buildings. *Energy* , 2647-2653.

Hicks, M. J. (2004). *Problem Solving and Decision Making.* London: Thomson Learning.

Hoffman, S. L. (2007). *The Law and Business of International Project Finance.* Cambridge University Press.

Jack, S. (2007). Location location location. *Drapers* , 12-13.

Jensen, M. C. (2001). Value Maximization, Stakeholder Theory, and the Corporate Objective Function. *Journal of Applied Corporate Finance* , 8-21.

Kuehne + Nagel. (2013). *Madagascar warehouse Medel, Tiel.*

Lamb, S. (2008). A guide to shedding the costs. *Sustainable Business* , 42-43.

Leach, J., & Melicher, R. (2006). *Entrepreneurial Finance.* Mason: Thomson South-Western.

Lin, H., & Darnall, N. (2010). Strategic Alliances for Environmental Protection. In J. Sarkis, *facilitating Sustainable Innovation through Collaboration* (pp. 233-246). New York: Springer.

Løken, E. (2007). Use of multicriteria decision analysis methods for energy planning problems. *Renewable & Sustainable Energy Reviews* , 1584–1595.

Nikolic, D. M., Jednak, S., Benkovic, S., & Poznanic, V. (2011). Project finance risk evaluation of the Electric power industry of Serbia. *Energy Policy* , 6168–6177.

Northwind. (2012). *How to finance a renewable infrastructure project in Belgium.* Retrieved May 13, 2013, from Northwind: http://www.northwindenergy.eu/uploads/20120628-How-to-finance-a-renewable-energy-infrastructure-project-in-Belgium.pdf

Ortiz, O., Castells, F., & Sonnemann, G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA. *Construction and Building Materials* , 28–39.

Pellenbarg, P. (2002). Sustainable Business Sites in the Netherlands: A Servey of Policies and Experiences. *Journal of Environmental Planning and Management* , 59-84.

Post, J. E., Preston, L. E., & Sachs, S. (2002). Managing the extended enterprise: The new stakeholder view. *California Management Review* , 6-28.

Rai, D. S. (2011). Assessment of CO2 emissions reduction in a distribution warehouse. *Energy* , 2271-2277.

Roberts, B. (2004). The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. *Journal of Cleaner Prodcution* , 997-1010.

Roy, M. (2010). Green warehouse. *ASHRAE Journal* , 64-70.

Sakr, D., Baas, L., El-Haggar, S., & Huisingh, D. (2011). Critical succes and limiting gactors for eco-industrial parks: global trends and Egyptian context. *Journal of Cleaner Production* , 1158-1169.

Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner prodcution* , 397-409.

Smith, R. C., Walter, I., & DeLong, G. (2012). *Global Banking.* Oxford University Press.

Tang, L., Shen, Q., & Cheng, E. (2010). A review of studies on Public–Private Partnership projects in the construction industry. *International Journal of Project Management* , 683–694.

Tsamboulas, D. A., & Dimitropoulos, I. (1999). Appraisal of investments in European nodal centres for goods - freight villages: A comparative analysis. *Transportation* , 381-398.

Tsamboulas, D., & Kapros, S. (2003). Freight village evaluation under uncertainty with public and private financing. *Transport Policy* , 141-156.

Tudor, T., Adam, E., & Bates, M. (2007). Drivers and limitations for the successful development and functioning of EIPs (eco-industrial parks): A literature review. *Ecological Economics 61* , 199-207.

Unilever. (2013). *Our history*. Retrieved March 4, 2013, from Unilever Web site: http://unilever.com/aboutus/ourhistory/

Unilever. (2012). *Unilever Sustainable Living Plan - Progress Report 2011.* Rotterdam: Unilever N.V.

Unilever. (2013). *Unilever Sustainable Living Plan*. Retrieved Februari 21, 2013, from Unilever: http://www.unilever.com/sustainable-living/uslp/

Walter, I., & Smith, R. C. (1998). *Global captial markets and banking.* McGraw-Hill Publishing Co.

Winkler, H., & Seebacher, G. (2011). Management of freight villages: findings from an exploratory study in Germany. *International Journal of Logisecs Research adn Applications: A Leading Journal of Supply Chain Management* , 271-283.

Wu, J., & Haasis, H. (2013). Converting knowledge into sustainability performance of freigh villages. *Logistic Research* , 63-88.

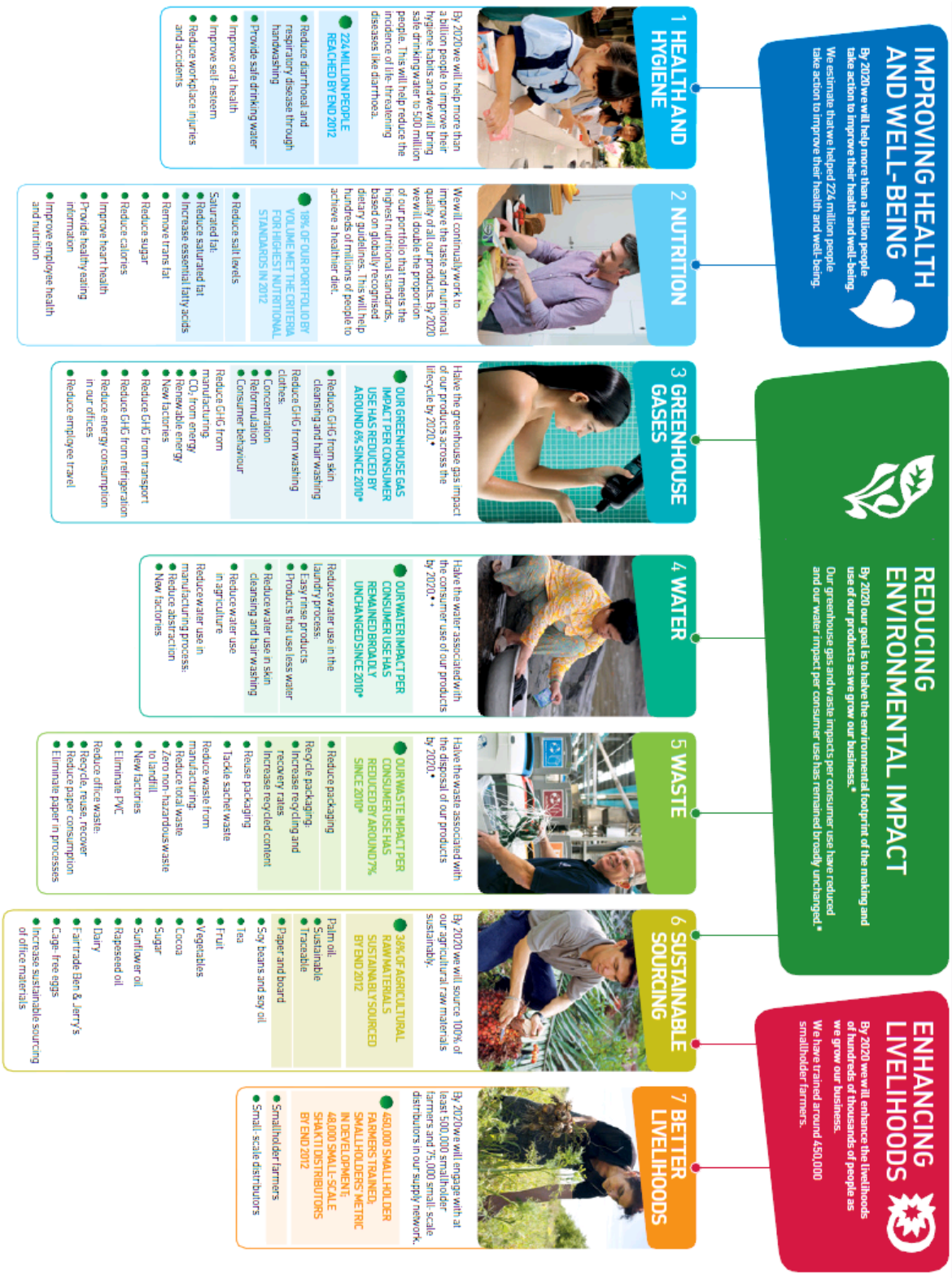
Wu, J., & Haasis, H. (2011). Knowledge-based Stakeholder Collaboration for Sustainable Development of Freight Villages. *17th International Conference on Concurrent Enterprising.*

Yescombe, E. R. (2002). *Principles of Project Finance.* Academic Press.

Yin, R. K. (2003). Collecting Case Study Evidence. In R. K. Yin, *Case Study Research: Design and Methods* (pp. 98-125). SAGE Publications.

Appendices

Appendix 1: Unilever Sustainable Living Plan commitments and targets



Appendix 2 Interview questions

Questions based on project finance and inter-firm collaboration literature (Tsamboulas & Dimitropoulos, 1999).

Project experts

Colruyt and Unilever Heilbronn

- Can you give a general description of the project?
  - Area
  - Project objectives
  - Sustainable option(s)

- How did you come up with the idea of inter-firm collaboration for this project?

- What does the organizational structure of the collaboration/alliance look like? What parties are involved in ownership?

- What does the capital structure of the collaboration/alliance look like? What is the percentage of equity and debt?

- What are funding sources for investments?

- In what areas were agreements made? Which of those were contract based?

- What risks did you encounter?

- What methods were used to estimate elements of the (risk) appraisal?

- What are the results of the collaboration/alliance?

- What are lessons learned from the collaboration/alliance?

Appendix 3: Literature search on sustainability options

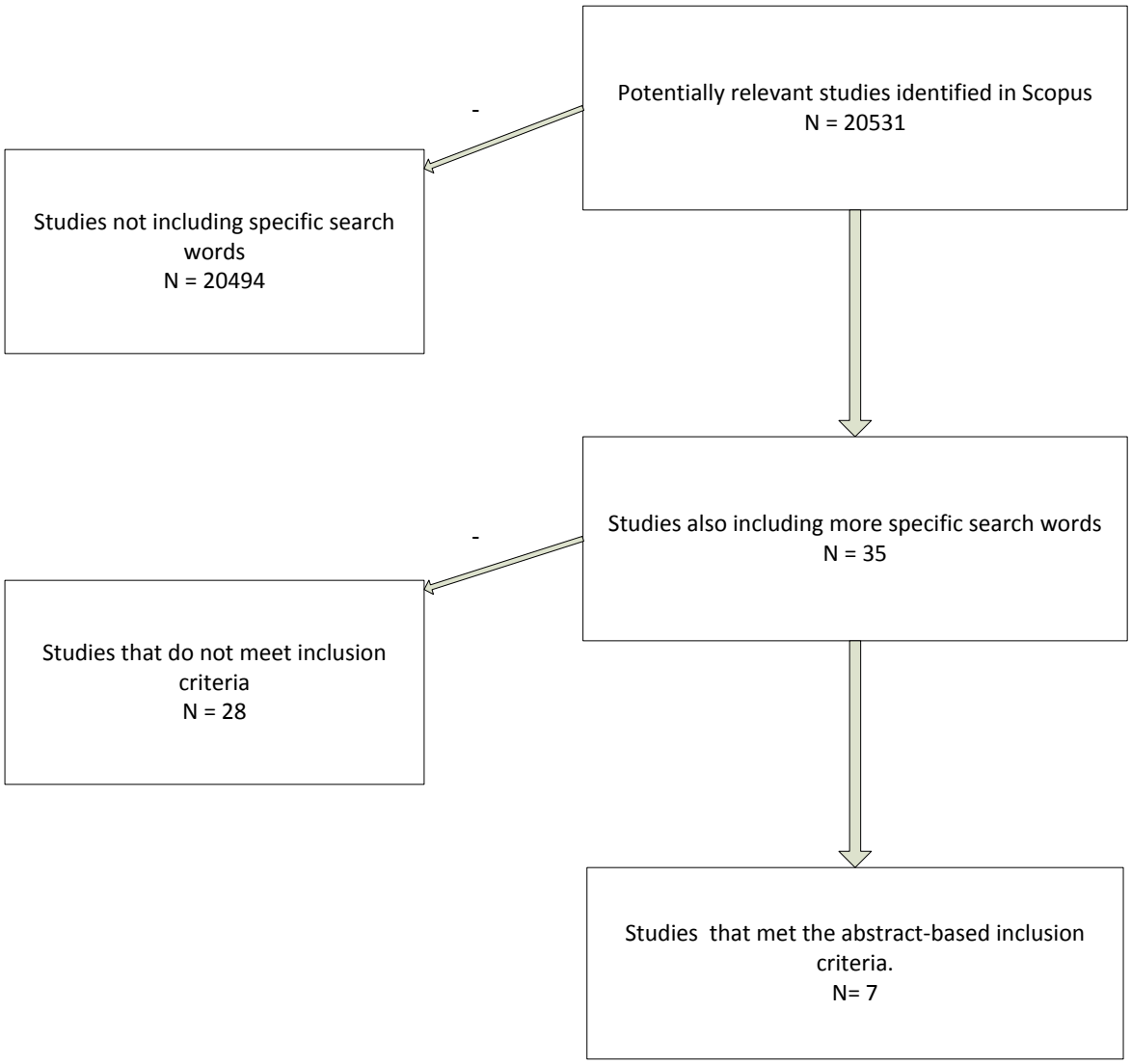
Sources	Scopus
First shift	search words: sustainab* OR CO2 AND build*
Second shift:	extra search word: warehous*
Third shift	abstract-review based on inclusion and exclusion criteria

Inclusion criteria:

Articles about a case study of sustainable warehouse building
Articles with options for sustainable warehouse building

Exclusion criterion:

Articles that not about the sustainable building of warehouse buildings



Articles:

- Fieldson, R., & Siantonas, T. (2008). Comparing methodologies for carbon footprinting distribution centers. Paper presented at the COBRA 2008 - Construction and Building Research Conference of the Royal Institution of Chartered Surveyors.

- Giulani, I., Aston, W., & Stewart, A. (2009). The design and development of an adaptable modular sustainable commercial building (Co2nserve) for multiple applications. International Journal of Ventilation, 8(2), 123-133.

- Han, H. J., Jeon, Y. I., Lim, S. H., Kim, W. W., & Chen, K. (2010). New developments in illumination, heating and cooling technologies for energy-efficient buildings. Energy, 35(6), 2647-2653.

- Jack, S. (2007). Location location location. Drapers, (31/MAR.), 12-13.

- Lamb, S. (2008). A guide to shedding the costs. Sustainable Business, (147), 42-43.

- Rai, D., Sodagar, B., Fieldson, R., & Hu, X. (2011). Assessment of CO2 emissions reduction in a distribution warehouse. Energy, 36(4), 2271-2277.

- Roy, M. (2010). Green warehouse. ASHRAE Journal, 52(3), 64-70.

Authors	**Main subject**	**Empirical validation**
Fieldson and Siantonas	Materials and processes of the construction	Case study
Giulani	Natural light, cooling and ventilation	
Han et al.	Illumination, heating and cooling	
Jack	Warehouse location	
Lamb	Sustainable installations	
Rai et al.	Design strategies	Computer simulation program
Roy	High-efficiency lighting and cooling	Case study

Appendix 4: Sustainability options decision analysis

		MUSTS		WANTS							
		Little negative effect on the operation	Total increase in sustainability	Improvement of the working environment	Low effort for implementation	Low costs	Increase ecological sustainability	Marketable	Increase in BREEAM score	Weighted score	Advice
Heating	Minimum score →	4	6								
Insulation (Rc 3.5)		4	9	4	4	5	5	2	4	69	Do
Insulation (Rc 5.0)		4	7	3	4	3	4	2	2	49	Don't
Thermographic assessment (inside out)		4	9	4	4	4	5	4	3	66	Do
Thermographic assessment (outside in)		4	9	4	4	4	5	4	3	66	Do
Trombe Wall		4	3	1	1	3	2	4	2	38	Don't
Coloring of outside walls		5	5	3	3	4	2	3	2	47	Don't
Coloring of the roof		5	5	3	3	4	2	3	2	47	Don't
Air curtains for loading docks		4	8	4	4	4	4	3	3	60	Do
Inflatable seals for loading docks		3	7	4	3	2	3	3	3	45	Don't
Central temperature regulation		4	7	4	3	3	3	2	3	48	Don't
Humidity control		5	8	5	3	4	3	2	3	55	Do
Combined heat and power installation											Research
Heat recovery from ventilation		5	6	3	5	4	3	3	3	55	Do
Acoustic alarm for warehouse doors		4	6	2	4	5	4	3	4	63	Do
Green roof		2	6	3	3	1	3	4	4	42	Don't
Green façade		5	7	3	3	3	4	5	3	56	Do
Solar thermal collectors											Research
Air/Ground Heat pump + Under floor heating (office)											Research
VRF system (office)											Research
Radiation heating + fans		5	7	4	5	4	3	3	3	57	Do
Air heaters		5	4	2	5	4	2	3	3	49	Don't

Lighting		Little negative effect on the operation	Total increase in sustainability		Improvement of the working environment	Low effort for implementation	Low costs	Increase ecological sustainability	Marketable	Increase in BREEAM score	Weighted score	Advice
Determination of required light levels		5	10		5	4	3	5	3	4	63	Do
Determining most effective location of light sources		5	9		5	4	4	4	2	3	60	Do
Windows (east and west side)		4	10		5	3	3	5	4	4	64	Do
Daylight installations (skylights, solatubes)		2	8		4	2	3	4	4	3	55	Don't
Intelligent lighting/motion sensors		4	7		3	4	4	4	3	3	58	Do
Flooring with a reflective substance		4	5		3	2	3	2	2	2	39	Don't
Ceiling with a reflective substance		4	7		4	3	4	3	2	3	53	Research
LED lighting												Research
Fluorescent TL5 lighting (high frequency and dynamic)		5	6		3	3	4	3	4	4	57	Do
Water												
Motion sensors for taps and showers		5	7		3	5	5	4	3	4	66	Do
Double flush systems and flush disruptors for toilets		5	7		3	5	4	4	3	4	61	Do
Leak detection system		5	6		3	3	2	3	3	3	43	Don't
Rainwater harvesting and usage of wastewater		5	6		3	2	3	3	3	3	47	Don't
Energy												
Power consumption (sub)meters		4	6		3	4	4	3	3	5	58	Do
PV panels												Research
Wind turbines												Research
Waste												
Stimulating waste segregation		4	7		3	4	5	4	3	5	67	Do
Compressing/cracking of waste		4	6		3	4	5	3	3	4	61	Do
Origin of building material		5	7		3	3	3	4	4	4	56	Do

Appendix 5: Literature review eco-industrial parks

Sources	Scopus
First shift	search words: eco-industrial networks OR eco-industrial park OR eco-industrial development
Second shift:	extra search word: success factor OR limitation OR challenge
Third shift	abstract-review based on inclusion and exclusion criteria

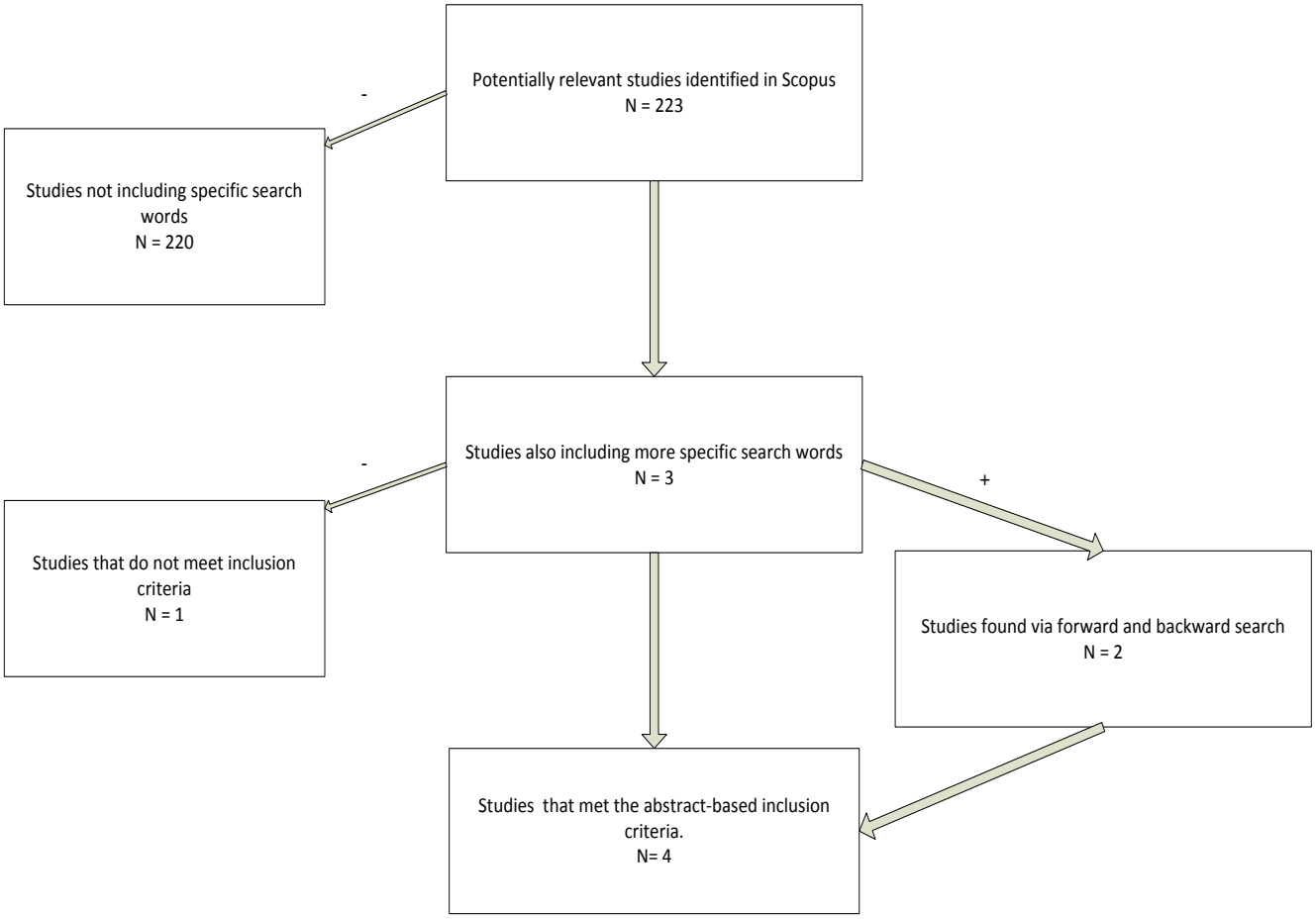
Inclusion criteria:

Articles about a case study of EIPs
Articles with success factors, limitations or challenges of EIPs

Exclusion criteria:

Articles that are not about EIPs
Articles too specific about EIPs in a certain region

Forward and backward search



Articles:

- Sakr, D., Baas, L ., El-Haggar, S., Huisingh, D., Critical success and limiting factors for eco-industrial parks: Global trends and Egyptian context (2011) Journal of Cleaner Production, 19 (11), pp. 1158-1169.

- Tudor, T., Adam, E., & Bates, M. (2007). Drivers and limitations for the successful development and functioning of EIPs (eco-industrial parks): A literature review. Ecological Economics, 61(2-3), 199-207.

- Roberts, B. H. (2004). The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: An Australian case study. Journal of Cleaner Production, 12(8-10), 997-1010.

- Pellenbarg, P.H. Sustainable business sites in the Netherlands: A survey of policies and experiences (2002) Journal of Environmental Planning and Management, 45 (1), pp. 59-84.

Authors	**study**	**Success factors**	**limitations**
Sakr et al.	Literature review + case study (Egypt)	X	X
Tudor et al.	Literature review	X	X
Roberts	Theory + case study (Australia)	X	X
Pellenbarg	Theory + case studies (the Netherlands)	X	X

Appendix 6: Literature review freight villages

Sources	Scopus
First shift	search words: freight village
Second shift	abstract-review based on inclusion and exclusion criteria

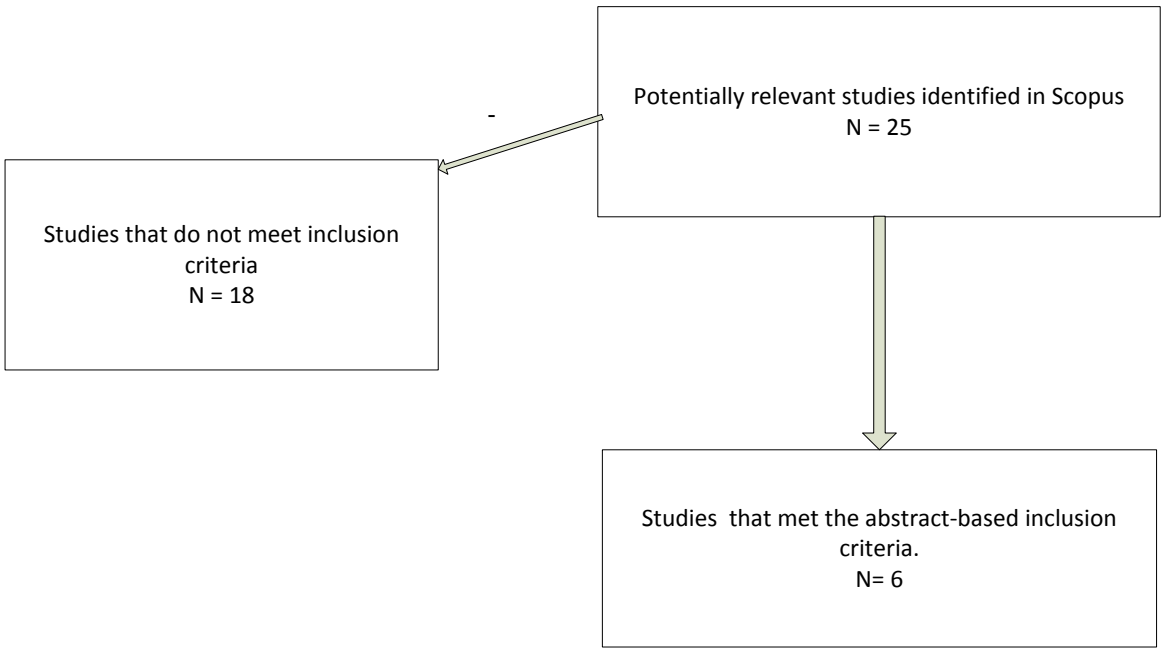
Inclusion criteria:

Articles about a case study of freight villages
Articles with success factors, limitations or challenges of freight villages

Exclusion criteria:

Articles that are not about freight villages
Articles too specific about freight villages in a sector

Forward and backward search



Articles:

- Wu, J., & Haasis, H. -. (2013). Converting knowledge into sustainability performance of freight villages. Logistics Research, 6(2-3), 63-88.

- Wu, J., & Haasis, H. -. (2011). Knowledge-based stakeholder collaboration for sustainable development of freight villages. Paper presented at the 2011 17th International Conference on Concurrent Enterprising, ICE 2011 - Conference Proceedings,

- Winkler, H., & Seebacher, G. (2011). Management of freight villages: Findings from an exploratory study in Germany. International Journal of Logistics Research and Applications, 14(4), 271-283.

- Tsamboulas, D. A., & Kapros, S. (2003). Freight village evaluation under uncertainty with public and private financing. Transport Policy, 10(2), 141-156.

- Tsamboulas, D. A., & Dimitropoulos, I. (1999). Appraisal of investments in European nodal centers for goods - freight villages: A comparative analysis. Transportation, 26(4), 381-398.

Authors	**Study**	**Success factors**	**Limitations**
Wu & Haasis (2013)	Theory (stakeholder involvement)	X	X
Wu & Haasis (2011)	Theory (knowledge-based view)	X	X
Winkler & Seebacher	Exploratory study (Germany)	X	X
Tsamboulas & Kapros	Theory (PPP) + case study (Greece)	X	
Tsamboulas & Dimitropoulos	Theory (appraisal methods Europe)	X	X