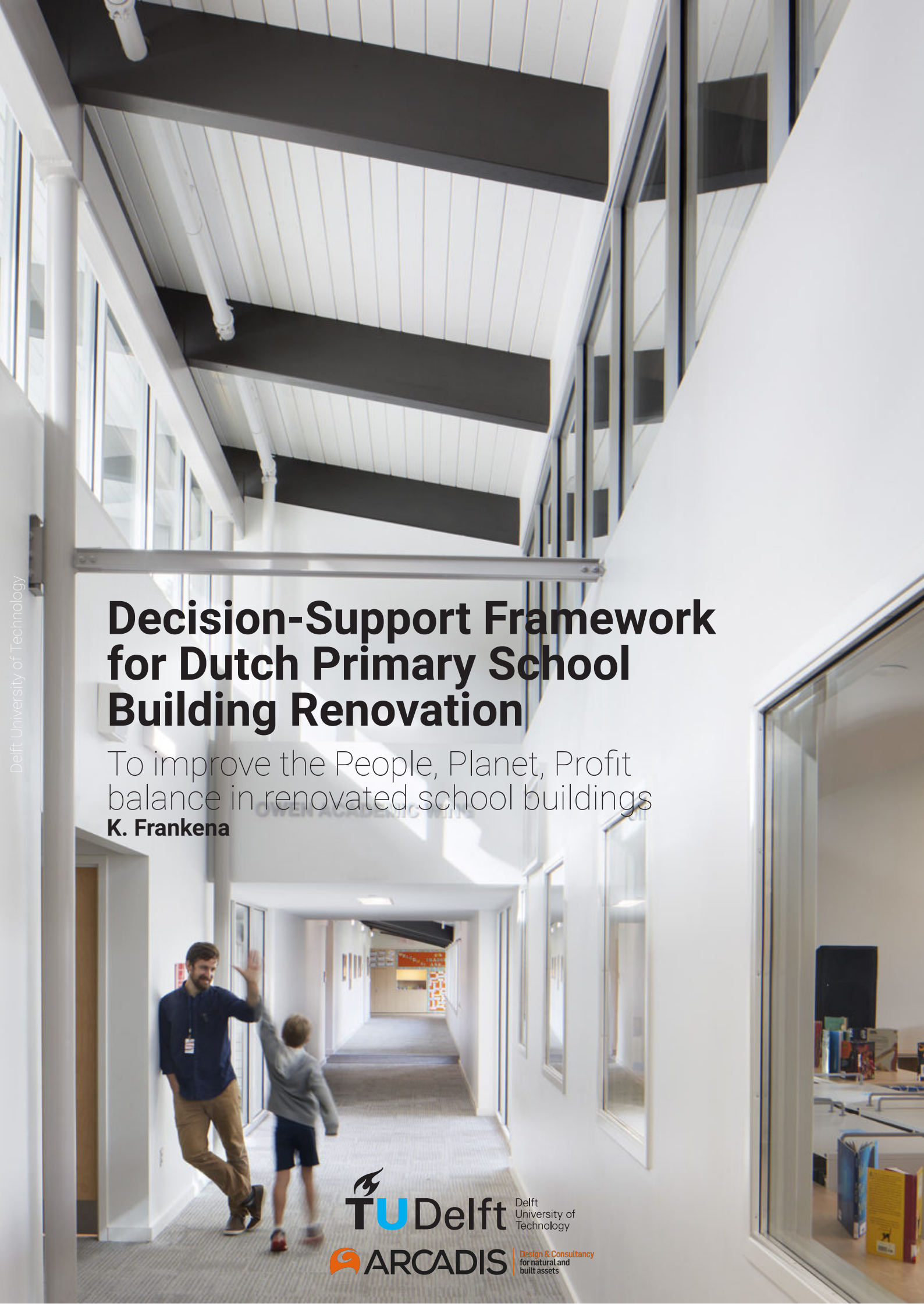

Decision-Support Framework for Dutch Primary School Building Renovation

To improve the People, Planet, Profit balance in renovated school buildings

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Delft University of Technology

TU Delft Delft University of Technology

ARCADIS Design & Consultancy for natural and built assets

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by

K. Frankena

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Preface

The past 7 years at the TU Delft have been a thrilling ride. Struggling through the bachelor, rushing through the master. I spent these past 7 months on the delivery of this thesis, and obtaining my MSc. title. It has been an honour to dedicate this time to contribute to two very important subjects; primary education and sustainability. Both often undervalued, yet so incredibly important to our future, and the future of the generations that follow. I humbly hope that this thesis bears some added value to the development of more sustainable, and healthy school buildings. The first prospects look promising.

I would like to take a moment to express my gratitude.

To my thesis committee, for taking the time to judge my work in our meetings. Special thanks to Ad, who has guided me throughout this entire project. You have always shown interest, dedication, and support. When doubt struck, you guided me in the right direction, providing me with new, positive energy to continue my works.

To Arcadis, for the opportunity to carry out this graduation internship. Enabling me to utilize their knowledge and experience. Special thanks to Eke. Your enthusiasm for the educational sector is contagious. Without your expertise and network, I would have never been able to deliver this thesis as it has become. Despite your busy schedule, you were always able to make time to discuss and review my works.

To my family, for always being there. Special thanks to my parents, Marjo and Peter. Thank you for the opportunity to go to university and giving me the freedom to enjoy my student life. Also thank you for the regular, necessary kick up the backside.

To Jessica, without your endless and tireless support I would have never been able to finish my student career the way I have. You have been able to keep me motivated when times were tough. I look forward to our time together in Amsterdam and beyond.

Thank you all.

K. Frankena
Delft, November 2017

Summary

International attention towards energy efficiency improvement is growing, pressuring the built environment to become more sustainable. Part of this energy efficiency improvement must be achieved at Dutch primary school buildings, but insufficient- and separation of budgets complicate the development of sustainable school buildings. Subject to this financial pressure, the current poor state of primary school buildings in terms of indoor environmental quality is, and will remain insufficient. Affecting performance, productivity and health of students and staff, and additionally having a monetary impact on school boards.

The inability to achieve energy efficiency in combination with good indoor environmental quality, within the available financial means, is for a large part explained by a lack of knowledge and experience in building-renovation by many Dutch school boards. Often, indoor environmental quality is one of the first things to suffer from insufficient funds. A decision-making framework is developed to provide school boards with the necessary knowledge and insight to better finance and organize renovation projects, providing more (financial) room to address the indoor environmental quality of their school buildings. Leading to more balanced school buildings in terms of People (indoor environmental quality), Planet (energy efficiency), and Profit (costs).

This framework comprises of a decision flowchart, supplemented by sustainable measure packages, that facilitates school boards in the renovation decision making process. The flowchart provides school boards insight in the decision-making process, (technical, financial and organizational) renovation opportunities, and effects of-, and on-, indoor environmental quality. This flowchart is developed using desk research, qualitative interviews and expert meetings. Then tested by obtaining qualitative expectations in interviews with school boards and a focus group with financial experts.

The expectations are that the decision-framework does provide more insight in the renovation decision-making process and opportunities, and that this could lead to better financing and organization of school building renovation projects. By raising problem awareness about indoor environmental quality effects, the framework is also expected to contribute to improved indoor environmental quality in renovated school buildings.

For further research, guiding school boards in contracting market parties is advised. This addition should present how to challenge contractors to come up with smart solutions to fulfill the ambitions of school boards. Furthermore, the flowchart should be tested by 'eenpitters' (school boards managing a single school), as they are often mentioned as key beneficiary. Also, the development of a digital version of the flowchart could enable easy use and sharing of the tool as well as easy coupling with other existing instruments.

Finally, for further development the following 'rules' should be kept in mind: the strength of the flowchart is in its simplicity, don't develop something new, bring together existing instruments, and use the language of the educational sector.

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List of Abbreviations

BENG	Bijna Energie Neutrale Gebouwen
CO	Carbon monoxide
CO_2	Carbon dioxide
dB	Decibel
EA	Economic Affairs (Ministry)
ECS	Education, Culture & Science (Ministry)
ENG	Energie Neutrale Gebouwen
EPC	Energy Performance Contracting
EU	European Union
ESCo	Energy Service Company
GFA	Gross floor area
GHG	Greenhouse Gas
IA	Internal Affairs (Ministry)
IAQ	Indoor air quality
IEQ	Indoor environmental quality
IHP	Integraal Huisvestigingsplan
ISIAQ	International Society of Indoor Air Quality and Climate
LCC	Life Cycle Costing
MOP	Meerjarenonderhoudsplan
NOM	Nul-op-de-Meter
NO_x	Nitrogen oxides
PE	Primary Education
PJ	PetaJoule
PoR	Program of Requirements
Ppm	Parts per million
RQ	Research Question
RVO	Rijksdienst voor Ondernemend Nederland
SBS	Sick Building Syndrome
SE	Secondary Education
TCO	Total Cost of Ownership
VOCs	Volatile organic compounds
VNG	Vereniging Nederlandse Gemeenten

1 Introduction

1.1. Situation sketch

On "Earth Day", April 22nd, 2016, the Paris Agreement was open for signature [59]. It's aim is to: (I) keep the global average temperature rise well below 2°C, (II) increase the ability to adapt to the adverse impacts of climate change and (III) adapt finance to the path that lowers greenhouse gas emissions and increases climate resiliency [90]. On November 4th, 2016, the agreement became official international law [58]. For the European Union (EU), this strengthened the importance of their climate strategies and targets. Namely, the 2020 climate and energy package [20], the 2030 climate and energy framework [21], and the 2050 low-carbon economy road map [22]. Their main targets are to bring down greenhouse gas (GHG) emissions by 20%, 40%, and 80% respectively.

Member states have committed themselves to the so called '20-20-20 targets', which includes a reduction of GHG emissions by 20%, an increase of renewable energy to 20%, and an increase of energy efficiency by 20% relative to 1990 [18]. Of these targets, the energy efficiency target is furthest from being achieved. Prospects are that only half of the 20% reduction will be achieved [19], forcing member states to act.

The Dutch government composed strategies to comply with these binding EU targets. They are divided into sector specific strategies.

> "The greatest energy saving potential lies in buildings" ([19], p.3).

The built environment accounts for 30% of the Dutch CO_2 emissions, therefore the 'Plan van Aanpak Energiebesparing Gebouwde Omgeving' [51] is created. This plan of action presents instruments as well as organizational- and financial measures that stimulate energy savings. Part of the energy efficiency improvement must be achieved in Dutch educational buildings.

A large contributor to energy efficiency initiatives in education is the RVO, Rijksdienst voor ondernemend Nederland. This institution is part of the Ministry of Economic Affairs (EA), but also works on behalf of other ministries and the EU. For the educational sector, the RVO set up several plans that stimulate and facilitate school boards in improving the sustainability of their buildings: Energie & Binnenmilieu Advies [96], Leidraad verduurzamen van schoolgebouwen voor basisonderwijs [98]. RVO also actively stimulates sustainability in education through Frisse Scholen [103] and Green Deal Scholen [24].

Because of its complexity and poor state, this research focuses on Dutch primary education. This introduction provides insight in the complexity and magnitude of the Dutch primary education sector.

What do we mean with sustainability?

Sustainability is a frequently used terminology. According to Johnston, Everard, Santillo, & Robèrt [2] around three hundred definitions of sustainability or sustainable development exist. Therefore, this research needs a clear definition. This research uses the definition of sustainability by John Elkington [32], who developed the triple bottom line theory, better known as the 3 P's: People, Planet, Profit (elaborated in section 4.1.2). This definition indicates that sustainability is determined by the optimization of all three P's.

For this research, the People dimension refers to the IEQ (indoor environmental quality) of primary school buildings, which influences health and performance of its occupants. The Planet dimension refers to the thermal energy performance of school buildings, and indirectly the damage inflicted on the Planet. The Profit

dimension refers to the life cycle costs of making school buildings sustainable. Sustainability is the optimization of the 3 P's, where the goals are to keep IEQ as high as possible, investment costs and energy demand as low as possible. Additionally, there are restrictions for each P. Such as legal boundaries (see section 4.3) and budget restrictions.

Primary education building stock

To create a sense of the magnitude of the Dutch primary education building task, some key figures are presented. According to a reference image of the Dutch utility sector [30], 52% of the total building stock has a residential function, the utility sector accounts for 36% and the remaining 13% is overlapping. The utility sector consists of approximately 600 million m^2 GFA (gross floor area), of which 80% is used for the services sector. Primary education is estimated to account for 3% of the total number of buildings in the services sector. Key figures on the size of Dutch primary education are presented in Table 1.

Table 1.1: Key figures primary education [86]

	Primary education
Total number of schools	6.985
Average floor area	1.300 m^2
Total number of students per school	1.546.00
Average number of students per school	224
Total number of school boards	1.085
School boards with less than 10 schools	75%
School boards with more than 10 schools	25%
Average number of schools per school board	6,4

Trends in primary education housing

At present, a maximum of 150 new school buildings are built every year [70]. At the current construction rate, the average age of school buildings will increase even further [97]. The demand for primary education will decline in the period till 2020, depending on location [93]. Growth areas will experience less decline than shrinking regions. After 2020, the demand for primary education increases slightly, influencing the building production and renovation. Currently, a third of the building production (in m^2) consists of renovation projects. In the period till 2020, this will grow to half of the yearly building production, and will remain so after 2020. The growth in renovation is explained by the expected reduction in educational housing demand, which causes new construction to drop and repair and renovation of existing buildings to rise. For this expected growth in renovation demand, and because renovation should be preferred from an environmental perspective [92], this research focuses on the renovation of school buildings, instead of new construction.

Primary education energy use

ECN [29] estimates that primary school buildings in 2011 on average used 12.900 m^2 gas and 22.600 kWh electricity per year. The total gas use by the primary education sector in 2008 was estimated at 105,9 million m^3 and the total electricity use at 284,3 million kWh. The total gas use was 4 Petajoule (PJ), which accounts for 2% of the total energy use by all utility buildings. The total electricity use by primary schools was 1 PJ, which is 0,6% of the total energy use by all utility buildings. The total expenditures for gas add up to €72,7 million and electricity adds up to €53,2 million in total in 2008 [29]. On average, each school building thus spent almost €10.000 on gas and €8.000 on electricity in 2008.

Converted to energy use per m^2, the primary education sector uses 12,9 m^3 gas per m^2 gross floor area and 22,6 kWh electricity per m^2 gross floor area'[29]. These figures date from 20006. In the meantime, the energy use could be much higher due to the increase in IT use in education, this trend is visualized in Figure 1.1.

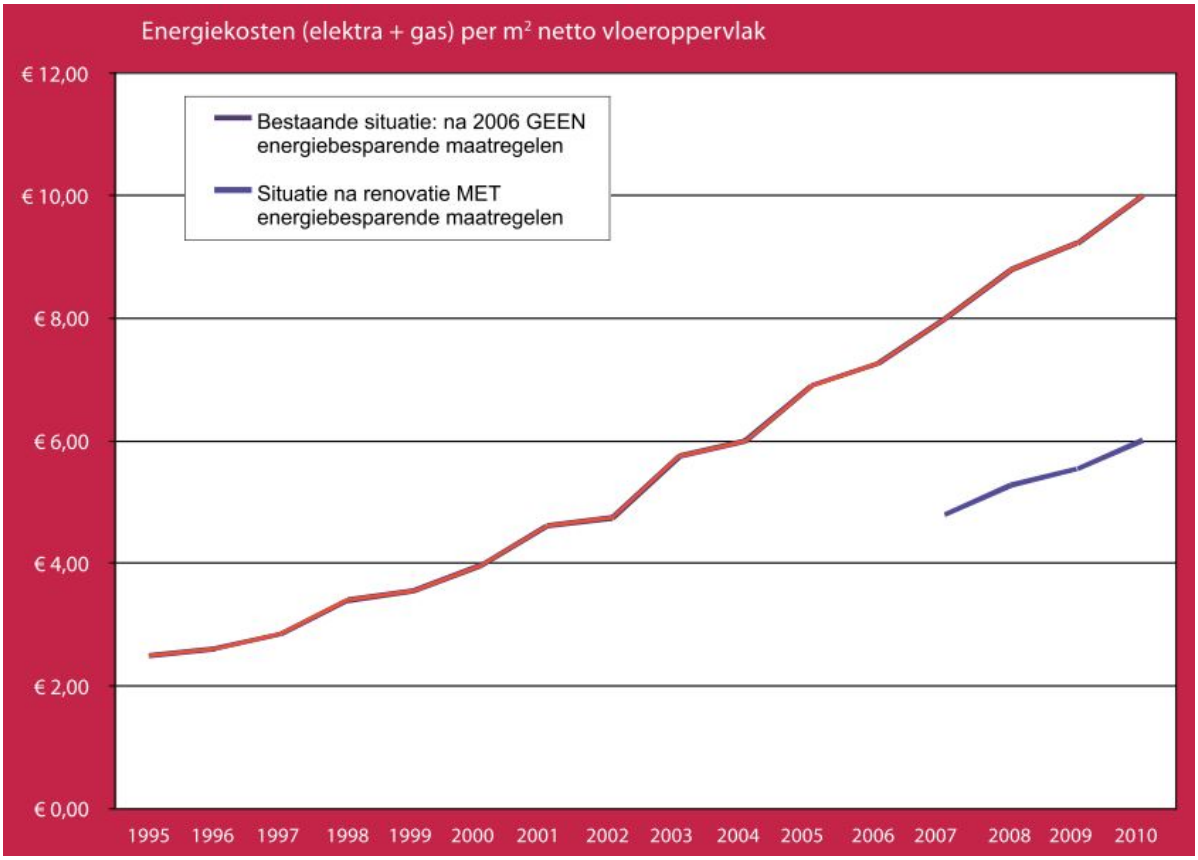

Figure 1.1: Trend in energy costs [15]

Financial pressure on education increases

On the first of June 2016, De Volkskrant published a list, in the corridors referred to as 'the menu', in which possible budget cuts are listed by the Ministry of Finance that together could save up to €50 billion [36]. Part of this list are retractable education investments adding up to 350 million euros. Additionally, possible savings on primary education are presented of about €200 million. In September 2016, the Ministry of Education, Culture & Science (ECS) announced lump sum subsidy cutbacks adding up to €255 million of which the largest cutbacks will befall primary education, namely €70 million [64]. These cutbacks will put pressure on the financial situation of primary schools and will inevitably be felt in the budgets for school buildings.

Indoor climate suffers

Inferior housing and budget overruns are the main problems in the building task of school boards [11]. With new budget cuts in prospect these problems could grow worse. One of the first things that suffers from budget cuts in education is the indoor climate [73], for example leading to the use of cheap materials in newly built school buildings or neglecting indoor climate measures [40]. Bad indoor climate affects the health, performance and productivity of occupants [105]. According to a survey by the RVO [98] over 80% of school boards apply sustainability measures to school buildings to reduce energy costs or to improve the indoor climate. Yet the state of primary school buildings remains poor.

In 2015 the RVO reported the situation in Dutch primary school buildings, the results are presented in Table 1.2. Approximately half of the school buildings are poorly insulated, almost all buildings have ventilation without heat recovery, most schools still use conventional fluorescent lighting and the indoor climate, especially the high CO_2 concentration, is insufficient. Figure 1.2 presents a comparison of CO_2 concentrations in schools, offices and prisons. The CO_2 concentration in schools appears to be much higher than in offices and prisons. Even highly sustainable school buildings appear to perform "not much better than schools based on more traditional designs" [109]. Experience from practice shows us that when specific attention is given to IEQ improvement, the IEQ is 3-4 times better than in other school buildings [15].

Table 1.2: State of primary school buildings [98]

Category	State	% total of schools
Insulation	Single glazing	31%
	Roof: not/poorly insulated	44%
	Façade: not/poorly insulated	41%
	Floor: not/poorly insulated	58%
Installations	Ventilation without heat recovery	89%
	Conventional boiler	11%
	Lighting - Conventional fluorescent lighting	61%
	Lighting - Lightbulbs	2%
Indoor environment	CO_2-concentration > 1200 ppm	80%
	Temperature > 25°C	45%
	Too high dust concentration	35%
	Too high velocity (causing draught in winter)	50%

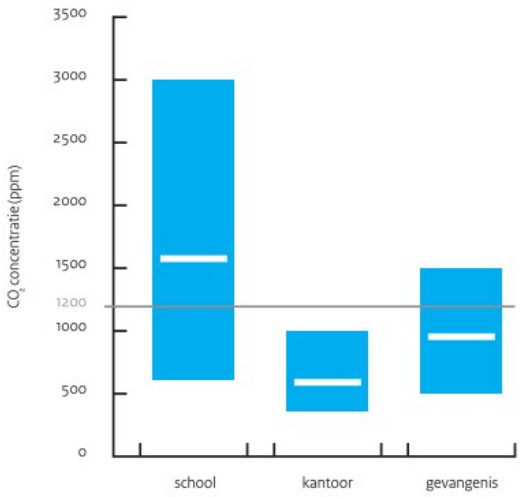

Figure 1.2: CO_2 concentration comparison between schools, offices and prisons [15]

Effects on health & performance

The indoor environmental quality (IEQ) of school buildings can affect health and performance of its occupants. Many researchers present proof of relationships between IEQ on occupant health or performance (see Table 1.3).

Table 1.3: Research on relations between IEQ and health & performance

Relation	Research
Indoor temperature on performance	Mendell & Heath, 2005 [49]; Pawel Wargocki & Wyon, 2007 [106]
CO_2 concentration on performance	Myhrvold, Olsen, & Lauridsen, 1996 [56]; Shaughnessy, Haverinen-Shaughnessy, Nevalainen, & Moschandreas, 2006 [85]
Ventilation rate on performance	Pawel Wargocki & Wyon, 2007 [106]
CO_2 concentrations on health	Myhrvold et al., 1996 [56]

Sick Building Syndrome (SBS) “consists of a group of mucosal, skin, and general symptoms that are temporally related to working in particular buildings.” ([17], p.1493). Studies indicate that health problems in schools are similar to the symptoms of SBS [61, 65]. In offices, increased sick leave results from lower levels of outdoor air supply and IEQ complaints [50]. An increased relative risk of 1.5-5 for respiratory illnesses and 1.1-6 for SBS symptoms are estimated for low ventilation rates compared to high ventilation rates [1]. This indicates the urgency to improve the educational building stock not only in terms of energy performance, but also in terms of IEQ.

Lack of experience & knowledge by school boards in managing renovation projects

The core business of school boards is to provide good education, not the construction or renovation of school buildings. Generally, school boards set up a program of requirements for renovation. Depending on the arrangements, this task can be transferred to the municipality. Repeatedly, indoor environmental quality is neglected in this program of requirements [73]. This could lead to suboptimal sustainability solutions with too little emphasis on the People dimension. Besides the lack in building experience in general, sustainability is a relatively new development concept, experiencing rapid new developments. Large school boards (managing >20 schools) are expected to possess more knowledge than medium (2-20 schools) and 'eenpitters' (1 school).

Table 1.4: Distribution of schools among school boards

School board size	Percentage of school boards
1 school	46%
2-5 schools	18%
6-10 schools	16%
11-20 schools	14%
>20 schools	6%

School boards join themselves with the fact that they lack knowledge [82]. They have insufficient insight in sustainable solutions for their buildings, accompanied by insufficient knowledge about financial opportunities and suspicion towards market parties. According to Ruimte-OK & Klimaatverbond Nederland (p.3, [82]) there are school boards that do not act because they describe themselves as "unconsciously incompetent" ("onbewust onbekwaam"), which does injustice to the renovation potential.

Both school boards and municipalities indicate the financing of renovation projects as the major barrier to start renovation projects [82]. Yet, there are plenty financing opportunities to make school building renovation feasible [77, 101]. Ruimte-OK & Klimaatverbond Nederland [82] questioned 135 school boards, of which 73% indicates that they do not possess knowledge of different financing forms. There is a large pool of knowledge regarding renovation opportunities, yet this knowledge is scattered throughout the market and poorly coupled [73].

Conclusions from the situation sketch

Given the situation sketch described above, the following expectations are developed:

It is expected that more knowledge and insight by school boards in technical, organizational and financing opportunities for renovation of school buildings leads to better organization and financing of renovation projects. With the current People, Planet & Profit balance leaning too much towards Planet and Profit, a shift is desired towards the People dimension. Better organization and financing of renovation projects should in turn lead to more financial space and attention towards the indoor environmental climate in renovation measures, resulting in a better balance between People, Planet & Profit in school building renovation. This study researches whether more knowledge and insights, could contribute to an improved People, Planet & Profit balance. The following chapters describes how.

2

Problem exploration

2.1. Problem definition

From the situation sketch the following four issues, regarding primary school buildings, are apparent.

1. Need for energy efficiency improvements. School boards are tying to become more sustainable. Yet this is complicated by the second issue.

2. Poor financing situation. Difficult financial circumstances put pressure on development of energy efficient schools. As a result, the third problem arises.

3. Poor indoor environmental quality. The current IEQ of school buildings is poor and not improving. Recent budget cuts reduce of attention for IEQ in school building renovation.

4. Lack of building-renovation knowledge by most school boards. School boards have little experience in renovation projects, because this is not their core business. Information about technical, financial and organizational opportunities is scattered and unclear. Lack of knowledge is expected to be an underlying factor for the other three issues.

To consider these issues simultaneously, school buildings need to become more sustainable as defined for this research. The following problem statement is considered:

Problem statement International climate agreements pressure the built environment to improve energy efficiency. Part of this energy efficiency improvement needs to be achieved in Dutch primary school buildings. Subsidy cutbacks impede investments and preserve the already poor state of indoor environmental quality in school buildings. There is an urgent need to improve the Dutch primary school building stock to create a good learning/work environment for students and teachers. But, lack of knowledge by school boards in building-renovation opportunities result in suboptimal school buildings. To improve the dimensional balance between People, Planet and Profit, school boards need to be facilitated knowledge and insight in the effects and opportunities of sustainability measures.

2.2. Research goals

The main goal of this research is to determine whether more knowledge by school boards leads to improved People, Planet & Profit balance in the renovation of primary school buildings. To do so, the following research goals are formulated.

1. Provide school-boards with knowledge and insights in the technical, financial and organizational opportunities in renovation projects. Better organized and financed projects are expected to lead to reduced financial pressure that lead to IEQ savings.

2. Determine qualitative expectations of the effects of more renovation knowledge by school boards on the optimization of the three P's.

2.3. Research questions

Given the formulated problem statement and research goals, The following main research question is formulated.

Research question

How can school boards take well-founded decisions about renovation of school buildings resulting in an improved People, Planet, and Profit balance?

This is broken down in the following sub questions (Table 2.1). For each sub question a research method and deliverable is formulated.

Table 2.1: Research sub questions

Nr.	Sub questions	Method	Deliverable	Section
1	What does sustainability mean for school buildings?	Desk research	Definitions of People, Planet & Profit	4.1
2	What is the current state of the Dutch primary school building stock?	Desk research	Extent of- and reason for the renovation task and Dutch school building typologies	4.2
3	What is the legal framework for school building renovation?	Desk research & Qualitative interview	Legal boundaries	4.3
4	How are decisions by school boards on sustainability measures currently taken?	Desk research & Qualitative interview	Organizational structure, stakeholder interests and decision-making process	4.4
5	What are the barriers in the development of sustainable primary school buildings?	Desk research & Qualitative interview	Barriers in sustainable school building renovation	4.5
6	What are the opportunities in school building renovation?	Desk research & Expert meetings	Technical, financial & organizational opportunities	4.6
7	What generic combination of technical measures can improve the sustainability of school buildings in renovation?	Desk research & expert meetings	Sustainable renovation measure packages	5.1
8	How can technical, financial and organizational opportunities be evaluated by school boards?	Desk research & expert meetings	Decision flowchart	5.2
9	To what extent does insight in renovation opportunities result in improved People, Planet & Profit balance in school building renovation?	Qualitative interviews & Focus group	Qualitative expectations of the effects of the decision flowchart and technical measure packages	6 & 7

2.4. Research scope

This research focuses solely on the renovation of Dutch primary school buildings. New construction is left out of consideration. This decision is made because of the expected growth of renovation projects [93] and because the renovation potential is currently underestimated [84]. Additionally, from an environmental impact perspective, "the renovation of buildings should be preferred over demolishing and rebuilding new ones because it greatly reduces the use of materials and demolition waste" ([92], p. 290).

The Global Building Performance Network formulate definitions for renovation [37]. They distinguish three major types of renovation:

1. Deep renovation
   Full economic energy efficiency improvement, focusing on the building shell, to improve the energy performance of a building.

2. Deep retrofit
   Replacement of existing systems in a building to improve the energy performance of a building.

3. Deep refurbishment
   Bringing the building back to its original state, and in that way improving the buildings' energy performance.

When this study refers to renovation, it includes the definitions for both deep renovation and deep retrofit. Furthermore, measures are included to improve the IEQ of the building.

The sustainable measure packages present the effects of technical measures on energy performance, air quality, temperature, lighting, noise, investment costs and payback time. Other effects or influences of these measures are disregarded. These effects only follow from physical changes to the building. Occupant behaviour is excluded, as well as the embodied energy of the building materials. Furthermore, the effects are indicated qualitatively. These choices are made, because of the generic character the flowchart and packages should have. Quantitative expectations are very dependent on the unique building characteristics, and can be determined in further research with e.g. case studies.

3

Research approach

This study applies several research methods. First, a solid foundation of information is formed using desk research. Available literature and reports are used to answer research questions 1-8. An informative interview is used as supplementary to the desk research. A school board member and educational housing expert is interviewed to fill in missing information and to reflect from practice on the conclusions drawn from desk research. Expert meetings are held to gain insight in the applicability of opportunities in practice and to shape the designs. Finally, qualitative interviews and a focus group are held to test the designs. Following these interviews and the focus group, the designs are finalized and qualitative expectations are determined. These methods are explained in further detail in this chapter. An overview of the research approach in presented in Figure 3.1.

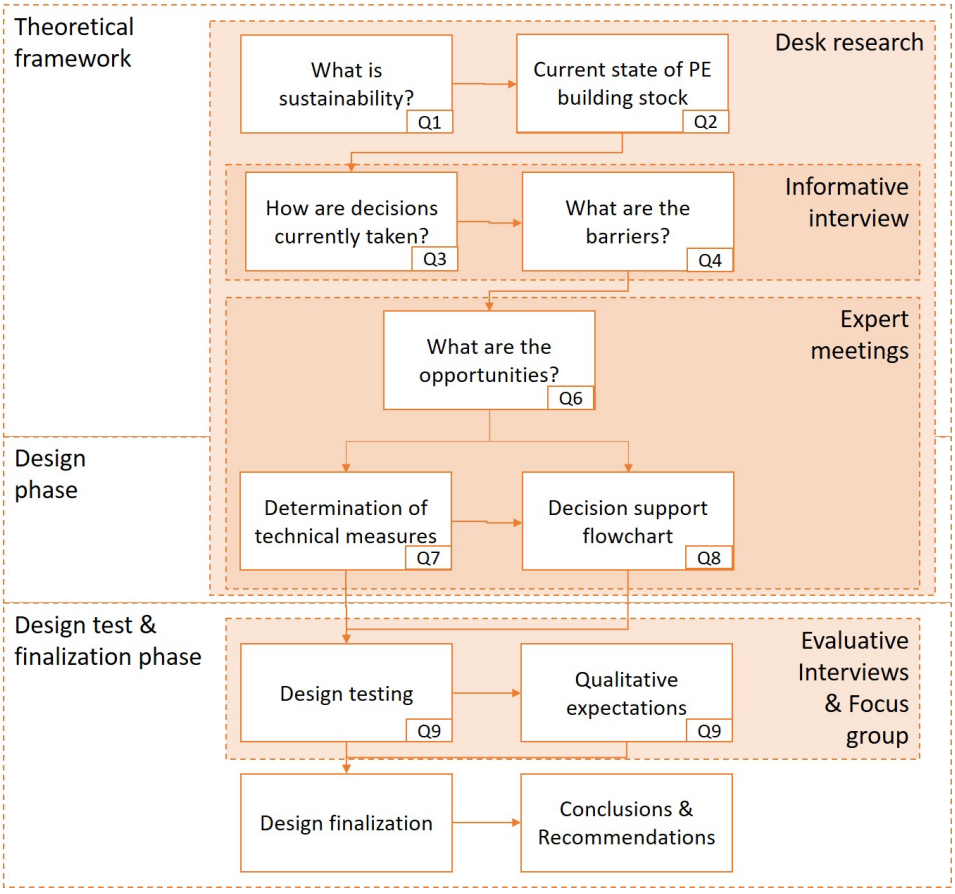

Figure 3.1: Research approach

3.1. Research methods

This section describes the research methods used to answer the research questions. For each research method, the expected findings are presented.

3.1.1. Desk research

This research starts off with extensive desk research. After formulation of the research questions and problem formulation, search terms and key sources are determined. These are then used to gather and select information to be processed in this research. This follows the systematic approach to desk research as described by De Afstudeerconsultant [88]. The search terms and main sources for the research questions are added:

1. The definition of sustainability for school buildings and further elaboration of energy performance and indoor environmental quality (Research Question 1 (RQ 1)).
    - Search terms: *Sustainability definition, Effects of IEQ/IAQ/Indoor climate on health/performance/ productivity, Primary schools.*
    - Main sources: *Elkington [32], Van Bueren et al. [92], and studies by EC Harris [28] & Wargocki [105, 106].*
2. The state of the Dutch primary education building stock (RQ 2). An overview of the current state of Dutch primary school buildings provides insight in the necessity of school building renovation and to improve the People, Planet & Profit balance.
    - Search terms: *Staat van basisscholen, Kwaliteit primair onderwijshuisvesting, Typologie basisscholen.*
    - Main sources: *Studies by ECN [29, 30, 60], RVO [97, 100], Versteeg [95], PRC [68].*
3. The legal boundaries for Dutch primary school building renovation (RQ 3).
    - Search terms: *Bouwbesluit, Activiteitenregeling, Wet Primair onderwijs, Uitvoeringsbesluit.*
    - Main sources: *Dutch laws and decrees [3–6].*
4. The way sustainability renovation decisions are currently taken (RQ 4). For this purpose, the organizational structure of the primary education housing system is discussed, with emphasis on stakeholder responsibilities and interests. This provides insight in the way this structure causes barriers for the People, Planet & Profit optimization in school buildings. A power-interest grid reveals the roles of stakeholders in the renovation decision-making. Furthermore, the decision-making process is determined, as far as possible.
    - Search terms: *Verantwoordelijkheden-, Rollen-, en Taken primair onderwijshuisvesting.*
    - Main sources: *Reports by Rijksoverheid [74, 75], Rijksbouwmeester [73], RVO [97], PO-Raad [71], and Algemene Rekenkamer [8].*
5. Barriers in renovation towards sustainable primary school buildings (RQ 5). The barriers, derived from literature, are divided in four categories: technical, organizational, financial and knowledge barriers. These barriers provide insight in the inhibitory factors that result in the key issues formulated in section 2.1.
    - Search terms: *Barrieres-, Problemen-, Probleemfactoren onderwijshuisvesting, impact energy efficiency IEQ/IAQ/Indoor climate.*
    - Main sources: *Reports by Rijksbouwmeester [73], Ruimte-OK [82], and RVO [97].*
6. Opportunities in renovation towards sustainable primary school buildings (RQ 6). From desk research, an overview of technical, organizational and financing opportunities is provided. These measures shall form outcomes in the decision flowchart. By providing insight in the pros and cons of each measure, considerations are determined that can be translated into questions in a decision flowchart.
    - Search terms: *Verduurzaamheidsmaatregelen, -pakketten onderwijshuisvesting, Financiering renovatie onderwijshuisvesting/schoolgebouwen.*

- Main sources: *Studies by Arcadis [10], RVO [102], ECN [60].*

Information is gathered using the following search engines: Google, Google Scholar & Science Direct. The reports and articles are collected using Mendeley.

Qualitative interview

The desk research is supplemented by a qualitative interview with a member of a school board. This interview provides insights from practice and aims to provide additional information which cannot be found in publications and/or reports. Main subjects that are treated in interviews with school boards or housing specialists are:

- The reasons for renovation (RQ 3).
- The service life planning process (RQ 3).
- The decision-making process (RQ 3).
- Barriers for sustainability renovation (RQ 4).

This interview is semi-structured [48]. A predetermined set of questions guides the interview towards the desired information. To stimulate flexibility during the interview, the set of questions is limited. Important subjects are discussed in detail by trying to expand on the interviewees' answers. Findings from the interview are added at the end of the relevant sections, labeled 'Insights from practice'. The interview questions are presented in Appendix D.

According to Baarda & De Goede ([12], p. 178) qualitative interviews are a good data collection method when it comes to, among others, knowledge. As this research focuses on the knowledge by school boards, this seems a good method to gather additional data. Following their view, the interview is held at the place where the interviewee feels comfortable, at his own work place. The interview questions are provided in advance with a personal and research introduction and an indication of topics. The questions are formulated clear and simple. Broadly formulated questions are clarified through an indication of answers. This way the interview remains on-topic.

The interview is processed by analyzing the data, and dividing the relevant data in several topics. Only one interview is conducted, which may affect the validity of this information. But, in combination with with in-house knowledge by Arcadis, this interview is considered to be sufficient to supplement the desk research with insights from practice.

3.2. Designs

In this study, two designs are developed. The first design, technical measure packages, follows from a reflection on existing measure packages, and provides school boards with insight in technical measures, and provides an indication of investment costs, payback period, and effects on energy & IEQ. These packages are coupled with the second design: a decision-support flowchart. This flowchart provides school boards insight in organizational, financing and technical opportunities (sustainable measure packages). Additionally, it provides insight in the considerations that need to be made in school building renovation to improve sustainability (the decision-making process).

3.2.1. Sustainability measure packages

Several sustainable measure packages or lists are developed by RVO, ECN and Arcadis. The packages by these institutions form a solid starting point, because these institutions have the necessary knowledge and networks to be progressive in this area of expertise.

Often, the focus of such packages is primarily on energy efficiency. In the development of new technical measure packages, the following steps are taken:

- Determining useful aspects from the existing packages,
- Improving the attention towards IEQ, and
- Reflecting the measures against Dutch school building typologies.

Additionally, insight is provided in the effects of the measures on energy efficiency, IEQ, investment costs and payback period. This should provide school boards with insights in the effects of the sustainability measures and guide towards school buildings with better People, Planet & Profit balance.

The effects of the measures are determined using literature [92], Arcadis expertise and projects [10] and a sustainable measure database [53]. This database is developed by Stimular [87], a foundation with close ties to business and governmental organization, aiming to accelerate sustainable business. With this information sustainability measure packages are drafted. These packages depend on the year of construction of a school building (building typologies), the horizon of the investment (payback period) and the sustainability ambition.

3.2.2. Decision flowchart

A flowchart is "a graphical representation of the specific steps, or activities, of a process" ([35], p.168). Flowcharts originate from computer programming in the 60's [35], but are nowadays also applied business and government, e.g. in the form of decision flowcharts. Fryman [35] sums up why flowcharts are powerful tools. For this research, the most relevant reasons for this research are ([35], p. 169):

- Flowcharts identify the value added steps
- Flowcharts provide a common basis of understanding of the process
- Flowcharts provide a visual representation of event (in this case: decision-) sequence
- Flowcharts map the logic of the (decision-making)process

An alternative to provide school boards with information and insights in school building renovation opportunities is to develop a matrix, presenting the opportunities with their benefits and disadvantages. The choice to develop a decision flowchart is made, because it presents the decision-making process, where a matrix does not. This is considered valuable additional knowledge. Additionally, a decision flowchart guides school boards through (multiple choice) questions, where a matrix only lists the information. This may reduce the effort for school boards and the threshold to use the flowchart.

By presenting the considerations that need to be made in primary school building renovation, school boards are guided through the decision-making process, eventually leading to technical, financing and organizational opportunities. All the while, the effects of indoor environmental quality are addressed. With this flowchart, sufficient information should be provided to support school boards in organizing and financing renovation, and trigger them to take indoor environmental quality improvements into account.
Fryman ([35], p. 170) describes the following steps for constructing a flowchart:

1. Determine the process to be flowcharted (desk research & qualitative interview)
2. Determine the level of detail (desk research & expert meetings)
3. Determine the process boundaries (desk research & expert meetings)
4. List the beginning activity (expert meetings)
5. List the sequential activities (expert meetings)
6. List the ending activity (expert meetings)

Although not in this exact sequence, these steps are taken in the development of the decision flowchart. The results from each step are presented in Chapter 5. The way by which these results are gathered is presented in brackets.

Expert meetings

In expert meetings, primary education housing experts from several Dutch market parties are brought together to discuss the issues at hand and how these issues can be tackled. The expert team participants are important players in the primary educational housing sector in the Netherlands and are described in Table 3.1.

These experts understand the needs of the primary education sector. This enables them to provide input on what school boards deem important, and what knowledge they have or need. Furthermore, they provide

input on the organizational, and financing opportunities. Each meeting has a different setting. E.g. the first meeting has the form of a brainstorm session, where the experts are encouraged to bring to the table as many themes, opportunities and constraints as possible, that should be covered in the flowchart and the following meetings. The key findings of each meeting are presented in Appendix C.

Table 3.1: Expert meeting participants

Function	Institution	
Senior advisor, Utility Buildings	RVO	Specialized in educational housing. Works for the Green Deal Scholen [24], on behalf of RVO.
Knowledge-& project manager	Ruimte-OK	(co)Developer of the Scholenbouwwaaier [80], and Kwaliteitskader Huisvesting [81].
Managing director	BAM Techniek Energy Systems	Former president at the Dutch chapter of ISIAQ (International Society of Indoor Air Quality and Climate) [63].
Owner	Boot Advocates	Contracting and Procurement expert. Also, founding member of ESCoNetwerk Nederland [57].
Sector leader Education	Arcadis	20 years experience in educational housing (exploitation, sustainability). Also, supervisor at KPOA Amersfoort [9] and member of the Dutch Green Building Council [23]
Project leader	Arcadis	With experience in educational housing.

3.2.3. Design test & finalization methods

The designs are tested and evaluated in two ways: qualitative interviews and a focus group. Both methods are applied to test the designs in terms of workability and comprehensiveness. The interviews additionally provide qualitative expectations of the way the designs contribute to an improved People, Planet, Profit balance.

Focus group

In a focus group, several market players gather to reflect on the designs. Focus is on the workability of the designs. The attendees are selected based on their expertise and experience in financing and organizational opportunities in school building renovation. They know what questions need to be asked when determining financing and organizational options, and what the available opportunities are. Focus groups are a way to explore how points of view are constructed and expressed [44]. This way, it becomes clear what the attendees believe the flowchart should include, and how they extract this from their market and professional expertise. In Appendix D, the focus group procedure is presented. A possible drawback of a focus group is that it may evoke "group think" [45].

Due to the holiday period, only one focus group is organized. This focus group consists of members of financial institutions and a knowledge- and network organization. Organizing a focus group among school boards did not succeed, therefore additional qualitative interviews are organized. The focus group is attended by the following people:

- A senior manager at NLII (Nederlandse Investerings Instelling).
- An associate at NLII.
- A senior advisor at NIA (Nederlands Investerings Agentschap).
- A member of Platform 31, Projectleader School vol Energie.
- A senior advisor on utility buildings specialized in education at RVO.
- Sector leader education at Arcadis.

These attendees are selected based on their involvement and expertise in school building renovation. The attendees are specialized in financing school building renovation and construction.

The NLII is currently developing a new organizational framework for the Dutch educational sector, similar to the Belgium example, where with a PPP-construction a Design, Build, Finance & Maintain (DBFM-)formula is applied to coordinate the improvement of Dutch school buildings [94].

The NIA facilitates both public and private entities by bringing finance closer. Frisse Scholen is one of the themes they work on. Platform 31 is a knowledge- and network organization which works on actual issues in the built environment, a.o. the educational housing sector.

School vol Energie is a program that aims to find ways to renovate existing school buildings, with a common building typology or so called 'systeemscholen' [79]. The other attendees also participate in the expert meetings that are used in the development of the Decision Flowchart.

The focus group is organized at the NLII, which is in the same building and floor as the NIA. This way the attendees are at ease in their own environment during the focus group. At first, every attendee introduces him-/herself, explaining their role and interest in the educational housing sector. Then, a general introduction is given, that explains the reason for the development of the decision flowchart, the work that already has been done, and the decision flowchart itself. During the explanation, the attendees are free to directly respond to the flowchart. The questions are used to keep the conversation flowing.

Qualitative interviews

These interviews are held among school boards. Beforehand, they receive the designs and the interview questions, to give them time to evaluate them. The interview questions are presented in Appendix D. These interviews are also semi-structured. Apart from fou school boards, an employee of the municipality of Rotterdam is interviewed.

Qualitative interviews are used as a method to test the designs, because this enables the interviewees to express their views and experiences about the flowchart. In a quantitative interviews, e.g. surveys, it is not possible to delve deeper into the answers respondents give.

The aim of these interviews is to gather insight in:

- Sustainability ambitions of school boards.
- Way of-, and reasons for renovating school buildings.
- Knowledge level in renovation projects and opportunities by school boards.
- Workability and comprehensiveness of the designs.
- Expected effects of the designs on Indoor Environmental Quality in school building renovation.

These interviewees are selected, because they are at the forefront of sustainability renovation of school buildings, in terms of both energy performance and indoor environmental quality. Apart from this expertise, these school boards have many contacts within the educational sector, which allows them to know and understand the problems that are apparent in the sector. For these reasons they are considered experts in both educational housing, as well as understanding of the issues that are at play in the primary education sector.

The decision to interview school boards who can be considered as experts is made because their knowledge of the issues in the educational sector enables them to pinpoint the needs of the average Dutch school board. Their progressiveness in sustainable educational housing also allows them to present ways how school boards should tackle school building renovation, what considerations are important in the decision-making process and evaluate the opportunities that are presented.

4

Desk research

This chapter presents the data gathered during desk research. It provides an overview of what sustainability entails for Dutch primary school buildings (4.1), the current state of Dutch primary school buildings (4.2), the legal boundaries for school building renovation (4.3), how responsibilities in the Dutch primary educational housing sector are stipulated and how stakeholders are related (4.4), and finally the barriers (4.5) and opportunities (4.6) in school building renovation. Sections 4.4 and 4.5 are supplemented by means of an interview.

4.1. What does sustainability mean for school buildings?

Even though the term sustainability is frequently used, the exact meaning differs widely. According to Johnston, Everard, Santillo, & Robèrt [2] approximately three hundred definitions of sustainability or sustainable development exist. Therefore, this section explores the definition of sustainability for school buildings in this specific research and explains how this definition relates to the research problems and goals. The key definitions and aspects of sustainability in this research, energy efficiency and indoor environmental quality, are elaborated in more detail. Understanding of these key definitions is important to determine when buildings are sustainable from this research' perspective and how this sustainability can be reached.

4.1.1. Defining sustainability

Sustainability is often associated with the impact that we as people, or in this case buildings, have on the environment. In this view, sustainability can be defined as environmental sustainability. Morelli [54] formulated an extensive definition for environmental sustainability specifically:

> *"Meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them, and more specifically. . . , as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity."*([54], p. 6).

This definition very much focuses on the impact on the environment. In the case of buildings, this impact can be caused by the energy performance of a building, the behaviour of its occupants, the type of materials used and the re-use of materials (circularity or cradle-to-cradle). Yet this formulation of sustainability does not cover the full spectrum for this specific research.

Sustainability can also be determined by the ability to withstand time; to sustain. In the built environment, this refers to the fact that building can be used for a determined exploitation period. For example, geographic changes such as the aging population changes the housing demand. Also for primary school buildings the housing demand can change. For example, the number of primary school students could change, the number of students per classroom or the form of education. This asks for a certain degree of flexibility in primary school buildings, which can be defined as (part of) sustainability. Again, this is not the focus for this research.

This study follows the triple bottom line theory by John Elkington [32], better known as the 3P's: People, Planet, Profit. This definition of sustainability is based upon the balance between these three dimensions. The Planet dimension can be as broad as described by Morelli [54], or solely on energy or material use. The People dimension refers to the social performance, or whether actions are socially responsible. Finally, the Profit dimension revolves around the profitability of sustainability measures. If adjustments are not affordable, sustainability improvements will not come off the ground. The following section explains why Elkington's definition of sustainability closely links with the issues at hand in this research.

4.1.2. The triple bottom line

Three of the four key issues in this research are energy efficiency, the financial situation and indoor environmental quality (Section 2.1). These components can be classified by the triple bottom line framework by John Elkington [32] as People, Planet and Profit. Although this framework is originally developed for corporate sustainability purposes, it is also applicable to sustainable development in the built environment.

The energy component aims at energy improvement of school buildings. Lower demand reduces the need to generate energy. With the share of renewable energy generation in the Netherlands only around 5-6% [33], this means that our energy demand leaves a significant ecological footprint.

The poor state of the indoor environment in Dutch primary schools can be placed within the People dimension. It is important to lower the impact on our environment, yet people should not suffer from energy saving measures. As shortly discussed in the introduction, measures to save energy could impact occupants' health and performance and should therefore consider the IEQ.

The existing financial structure indicates the importance of Profit. A major reason why sustainable measures are not thriving is because the profitability is deemed questionable, or difficulties in financing the project. For the transition towards sustainable school buildings it must therefore be affordable, or preferably financially attractive. In this research this affordability is expressed in investment costs and payback periods. Investment costs can function as determinant for how the technical measures can be financed. Payback periods present insight in the necessary exploitation time for the technical measures.

Tensions between the three P's are inevitable. When too much focus is on Profits, Planet and/or People might suffer. The other way around, investments to improve Planet or Profit might harm Profits. This research is therefore built upon Elkington's framework to take into account all three bottom lines and achieve true sustainability. Guzman, Pereira Roders, & Colenbrander [39] visualized this relation (Figure 4). They state that it is commonly agreed that "the development of a given territory, in order to be considered sustainable, must integrate the qualities associated with the interactions of three dimensions"—social, economic, and environmental" ([39], p. 193)(Figure 4.1).

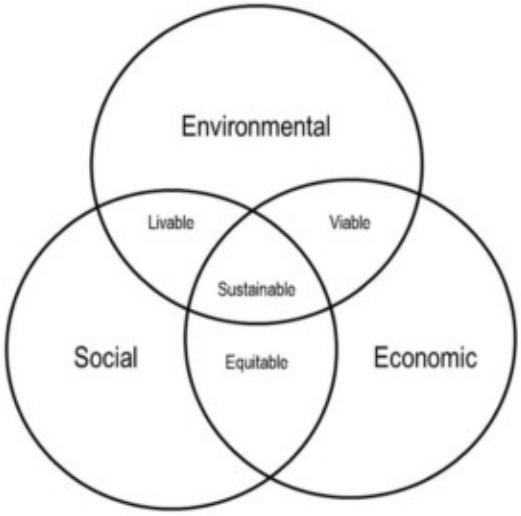

Figure 4.1: Dimensions of sustainability [39]

4.1.3. What is meant by energy performance?

This section dives deeper into the meaning of energy performance. It provides basic knowledge about how the energy efficiency, or Planet dimension, of a building can be improved. Energy performance is often associated with sustainability. Yet sustainability is not the sole purpose for reducing a buildings' energy use. Two other important reasons to save energy are cost savings and security of supply ([92], p. 119).

Improving the energy efficiency reduces the exploitation costs of a school building. financial benefits are an attractive reason for applying energy efficiency measures. The payback period of investments differs. The shorter the payback period, the earlier financial benefits are felt.

Security of supply is another reason to improve energy performance. Energy from most abiotic and biotic resources can deplete. As the first step in the Trias Energetica, or three step strategy, indicates; we should reduce our energy demand in order to extend the time we can use nonrenewable energy sources and thus extend the security of supply ([92], p. 315).

The third important reason to improve energy efficiency is to lower our impact on the environment. Energy in itself is not harmful for the environment, but our energy demand is a cause for environmental impacts. The use of fossil fuels causes the depletion of abiotic resources, the use of biomass causes the depletion of biotic resources and the emission of combustion products causes depletion of the ozone layer, global warming, acidification, eutrophication, smog, ecotoxicity and humane toxicity ([92], p. 119). Therefore, it is important to reduce the energy demand of our buildings to reduce impact on the environment.

Then what determines the energy demand? In general, the energy demand is dependent on the characteristics of the building, such as the size and type of walls, roofs and windows, type and thickness of insulation materials and the people and appliances present in the building. Occupants determine the energy demand through their numbers, time spent inside, their behaviour, and comfort preferences [92]. Thus, by altering these parameters, the energy demand of a building can be influenced. Furthermore, the outdoor temperature influences energy demand. In warm areas energy is needed for cooling, while in cold areas energy is needed for heating. How much energy is needed for heating or cooling is determined by the thermal energy balance, which takes the abovementioned aspects into account.

4.1.4. What is meant by indoor environmental quality?

This section explores what factors affect IEQ as well as the effects that the IEQ of a building can have on its occupants. Additionally, it indicates how the indoor environmental quality, or People dimension, can be improved.

On average, we spend 90% of our time indoor [91]. Most of it is spent at home, at work or in school. Dutch children spend approximately 930 hours a year at primary school [62]. Additionally, these children spend on average another 27.7 hours per week in childcare [34], which is often located in the very same school building. It is therefore important that the time spent inside a school building does not affect their health, performance or productivity, especially knowing that children have a greater susceptibility for pollutants than adults [49]. Besides children, teachers spent similar hours in school buildings.

What affects IEQ?

The general determination of- and causes for IEQ are described by Arjen Meijer in Bueren et al. [92]. Meijer describes five source categories that affect IEQ: chemical pollutants, biological pollutants, thermal comfort, noise and lighting. The first two sources are absorbed via inhalation or the skin and can cause serious health effects. The other three sources cause less health effects, but often cause annoyance. Outdoor pollutants such as traffic, agricultural and industrial activities can also affect health.

Chemical pollutants are caused by building materials, soil, consumer products and combustion gases. Building materials such as paints, glues and plastics can emit volatile organic compounds (VOCs). It should be noted that materials that do not emit VOCs often have worse effects on the environment in the production process, thus are not automatically better. Such trade-offs need to be considered. Stony materials such as bricks and concrete emit Radon, which can cause lung problems. The same is the case for soil, such as rocks, sand or clay. Consumer products such as cleaning agents and electronic equipment also emit VOCs. Combustion gases such as NO_x (nitrogen oxides), CO_2 (carbon dioxide) and CO (carbon monoxide) are emitted by geysers and gas stoves.

Living organisms emit biological pollutants. Most common are molds, house dust mites, plant and pet allergens, legionella and people. The first two live in moist places, legionella in water. From people, odors are the main pollutant.

Thermal comfort is determined by indoor air temperature, surface temperature, air movements, humidity, type of activity and type of clothes. Indoor air temperature PMV (predicted mean vote), or sensation vote, should range between -0.5-0 to achieve optimum work performance by occupants [47]. When the indoor temperature is low, warm surfaces like a wall, floor or roof can be comfortable. Vice versa, cold surfaces can be considered comfortable during high indoor air temperatures. Velocity of air can create a cold sensation, which is pleasant in summer, but not in winter. Humidity is often higher in summer than in winter. Very high humidity is deemed uncomfortable, but very low as well. Furthermore, spaces where high-level activities take place require lower temperatures and vice versa.

Noise nuisance can have outdoor (roads, traffic, construction activities) or indoor (equipment, appliances) sources. Air quality is closely related to noise comfort. Often windows, or ventilation ducts are closed by occupants because of outdoor noise sources or mechanical ventilation equipment is turned off, because of the noise it produces. This affects the quality of indoor air. Insulation of mechanical ventilation can prevent this.

Lighting can have adverse effects on the comfort level. Glare can be disturbing if it falls directly in eyes or on computer screens. Too little lighting could be troublesome for activities such as reading and too little daylight can cause psychological problems such as winter depression [92]. Lighting also influences the energy performance of a building. If a lot of daylight enters, less artificial lighting is necessary and reduces the energy demand. While in summer it could increase the need for cooling. For this research, the considered aspects of IEQ are, as described above: air quality, temperature, lighting and noise.

Performance, productivity, health and monetary impacts of IEQ

Performance can be defined as "the ability of an individual to perform different mentally and physically demanding tasks and a measure of how well employees do what they are trying to do" ([105], p. 1). Productivity as a ratio between input (e.g. costs of maintaining equipment, wages) and output (e.g. products or services). As stated in the introduction, IEQ can have adverse effects on occupants through Sick Building Syndrome symptoms. The other way around, good IEQ can have positive effects.

EC Harris [28] states that students achieve 5-14% higher test scores and learn 20-26% faster in LEED certified buildings due to improved lighting. As well as a productivity improvement of 23% via better lighting, 1% via better ventilation and 3% via individual temperature control.

Furthermore, improvements in IEQ reduces health costs and can cause significant economic benefits through productivity and performance increase. Wargocki [105] states that 1% increase in productivity can increase performance by 1%, extend the effective time at work by 5 minutes per day, reduce sick absence by 2 days per year and compensate the annual costs of ventilation. A 10% increase in productivity can compensate the full costs of installation and exploitation of a building. The payback time for investments aimed at air quality improvements is generally less than 2 years.

More specifically for primary school buildings Wargocki [105] refers to the Danish example. With the presumption that students who perform better in primary school have a higher income in adult life, it is estimated that the socio-economic consequences of improved indoor air quality yield 0.1% of the Danish GDP. The economic benefits can also be explained by improved teacher performance, which can reduce overtime. Simple calculations estimate that 5% improvement in performance would result in net benefits of €0,10 per child per day after deducting costs for renovation. This indicates the individual and societal importance of IEQ.

Zeiler & Boxem [108] researched flaws in recent sustainable school buildings. It appeared that the IAQ (indoor air quality) in sustainable schools is not much better than in traditional schools. By focusing on the cost specification of schools, they indicate that a focus on energy efficiency, leading to lesser IAQ, can have adverse financial effects. Energy costs are estimated at only 1,2% of total costs, and personnel & replacement costs together account for 80,1% of total costs. Approximately 46% and 33% can be saved on gas and electricity costs respectively, accounting in the best case for 0,6% of total costs. While 2% increase in labour costs due to poor indoor environmental quality accounts for 1,6% of total costs. This indicates the monetary impact IEQ can have. The figures presented in this section are summarized in Table 6. These can function as striking facts or notions to point out the necessity and possible gains from IEQ improvement.

Table 4.1: Key figures primary education [86]

Subject	Research results	% Source
Lighting	Improved lighting can lead to: • 5-14% higher test scores, • 20-26% faster learning, and • 23% productivity improvement	EC Harris [28]
Air quality	Improved ventilation can lead to: • 1% productivity improvement	EC Harris [28]
Productivity	1% productivity increase can lead to: • 1% performance increase • Extend effective time at work by 5 minutes per day • Reduce sick absence by 2 days per year • Compensate the annual ventilation costs	Wargocki [105]
Productivity	10% productivity increase can: • Compensate full installation and exploitation costs of a building	Wargocki [105]
Temperature	Individual temperature control can lead to: • 3% productivity improvement	EC Harris [28]
Costs, energy, IEQ	Energy costs are ±1,2% of total costs, 46% and 33% can be saved on gas and electricity, representing: • 0,6% of total costs Personnel & replacement are ±80,1% of total costs, 2% increase in costs due to poor IEQ: • 1,6% of total costs	Zeiler & Boxem [108]

4.1.5. Conclusion

The triple bottom line theory presents the definition of sustainability for this research. The People dimension is captured by the IEQ and the impact this has on occupants. The Planet dimension is captured by the energy demand by school buildings. And the Profit dimension is captured by the affordability of sustainability improving interventions. The affordability is dependent the investment costs and payback period of the interventions and the way these interventions are financed. This section presents the interrelatedness of the three dimension, which complicates the road towards sustainable school buildings. It also presents possible benefits of IEQ improvements, indicating the missed opportunities due to poor IEQ.

4.2. Current state of the Dutch primary school building stock?

On average the Dutch primary building stock ages from the year 1976 [8]. The distribution of known years of construction of Dutch primary school buildings are visualized in Figure 4.2. According to the Algemene Rekenkamer [8] the functional and technical quality of school buildings varies. Often school buildings do not meet the minimum building requirements, and no, or barely no, action is performed against this.

The relatively old age of school buildings influences the performance in terms of energy, indoor environmental quality and structural condition. The latter is important to assess whether renovation is feasible, or new construction is inevitable. This is elaborated in this section. An overview of the state of Dutch school buildings indicates the urgency of IEQ improvement, and distinguishes typologies for school buildings. These typologies can be used in the development of technical measure packages. Finally, the extent of the renovation task is covered.

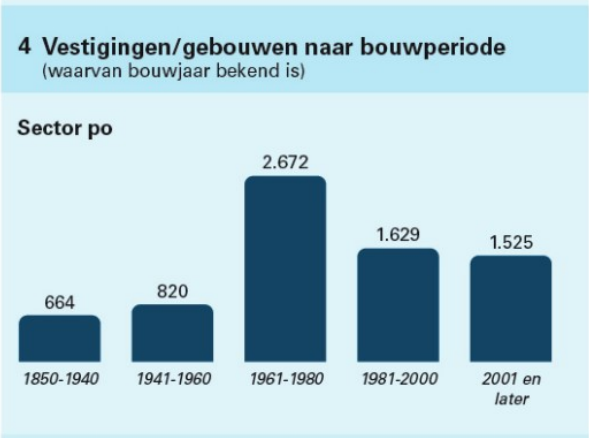

Figure 4.2: Years of construction of Dutch primary school buildings [8]

4.2.1. Energy demand

The largest cost item for energy in Dutch primary schools is space heating [31]. Followed by electricity use for lighting and ventilation (Table 4.2). The RVO studied the most applied energy saving measures in utility buildings between 2012-2015 [99], in which they state that, after health-care buildings, educational buildings apply most energy saving measures of all utility building types. They distinguish three energy saving measures: insulation, glass replacement and CV-boiler improvement.

On average 65% of all utility buildings has an insulated roof, of which, in case of school buildings, only 50% is of decent quality. Only 46% of utility buildings have entirely insulated façades, one third is not insulated at all. Approximately, half of the school buildings has no floor insulation. In utility buildings 22% has single glazing, 59% double glazing and 19% HR glazing. The main reason for new glazing in school buildings is breakage of windows. In most school buildings HR boilers are in place.

Table 4.2: Average primary energy use distribution in Dutch primary school buildings [107].

Source	Primary energy use [MJ/m^2]
Space heating	312
Tap water	15
Summer comfort (cooling)	46
Ventilation	183
Lighting	206

4.2.2. Indoor environmental quality

The air quality in Dutch school buildings is substandard, especially during the heating season (October 1st -May 1st) [95]. In 88% of the examined classrooms, the CO_2 concentrations are over 1200 ppm for on average 41% of class time. This is caused by either lack of ventilation capacity or through occupant behavior. In classrooms with natural ventilation, behavior is the major cause. Windows are not opened enough, because this leads to cold, draught and/or outside noises. Classrooms with mechanical ventilation often lack sufficient ventilation capacity to supply enough fresh air or are turned off because of noise nuisance.

The thermal comfort of classrooms is often poor. In over 40% of the classrooms, the thermal comfort is considered insufficient in summer. In 20% the maximum temperature of 23°C is exceeded during class hours. In 57% of the classrooms the minimum temperature of 19°C is not met during class hours (during winter).

In 47% of the examined classrooms, the background noise level exceeds the maximum allowable noise level of 35 dB ([4], art. 3.3). 18% of the classrooms even experiences noise levels over 40 dB. The major causes are outside noise, possibly causing teachers to close windows, resulting in less fresh air supply. Classrooms with mechanical ventilation experience noise disturbance from the ventilation system.

4.2.3. Structural condition

In a study on the maintenance of school buildings, the structural condition of 256 primary school buildings was investigated [68]. Several building components were examined, among others; façade, frames, roof, construction, and foundation. The state of primary school buildings appears to be reasonable (30%) to good (65%). Only 2% is qualified as moderate to bad, 3% is in excellent condition.

Plotted to year of construction (for both primary & secondary education, PE & SE), it is apparent that school buildings from the period 1960-1980 are in least condition: 53% good, 47% reasonable, compared to 71% good and 28% reasonable for <1960 and 77% good and 21% reasonable for 1980-200. Buildings from 2000 onwards are of best quality.

Given the overall 'good' to 'reasonable' structural condition of school buildings, renovation seems to be a possibility in most cases. The quality of building components such as the foundation are essential to the feasibility for renovation. If the foundation shows defects, new construction is often preferred. This was only the case in 4 of the 322 cases (both PE & SE).

4.2.4. Extent of the renovation task

The Netherlands has a total of about 8000 school buildings, of which over 6500 for primary education. Of the 8000 school buildings, 1000 are in bad condition and are in urgent need of renovation or replacement [97]. 2000 school buildings function sufficiently, but need energy and indoor environmental quality improvements. Approximately half of the school buildings is of reasonable- to good quality. The remaining 1000 school buildings experience vacancies, therefore interventions are not recommended. These numbers indicate the size of the renovation task that schools are facing.

4.2.5. Building typologies

Schilt [83] distinguishes three important building periods: before 1970, between 1970 and 2000, and after 2000. Typologies of school buildings from these periods according to Schilt are presented in Table 4.3.

Table 4.3: State of school buildings (archetypes) [83]

Year of construction	<1970	1970-2000	>2000
Ventilation	Natural	Mechanical exhaust	Balanced
Insulation	Very poor	Decent	
IEQ	IEQ standards rarely met, but not bad	Often very poor	Often poor ventilation

ECN [60] describes several reference buildings, based on building practices and regulations for these specific periods (Table 9). The blue cells present (the larger) changes in comparison with the previous building period. Two large transitions in building practices are apparent. Around the year 1975 new, stricter building standards were introduced. This resulted in changes in school construction, such as: insulation improvements (to R_c=1.3), school buildings switched from single to double glazing, HR-boilers were installed and natural ventilation to mechanical exhaust ventilation. In 1992, the 'bouwbesluit' was introduced, resulting in schools with improved insulation (to R_c=2.55), as well as balanced mechanical ventilation instead of only mechanical exhaust and time switches for lighting (veegpulsschakeling) instead of regular switches. These periods: <1975, 1975-1992 and >1992 can be used to distinguish what technical measures should be taken in these specific building periods.

Referentie	1	2	3	4	5	6	7
EPC	-	-	-	-	-	-	1,5
Bouwjaarklasse	Tot 1920	Van 1920 tot 1965	Van 1965 tot 1975	Van 1975 tot 1988	Van 1988 tot 1992	Van 1992 tot 1995	Van 1995 tot 2009
Rc vloer	0,15	0,15	0,17	0,52	1,3	2,53	3,5
Rcdak en gevel	0,2	0,36	0,4-0,9	1,3	2	2,53	3,5
glas Ur	Enkel; 5.2	Enkel; 5.2	Enkel; 5.2	Dubbel; 2.9	Dubbel; 2.9	Dubbel; 2.9	Dubbel; 2.9
Ketel	VR	VR	VR	HR107	HR107	HR107	HR107
Ventilatie	Natuurlijke toevoer, afvoer	Natuurlijke toevoer, afvoer	Natuurlijke toevoer, afvoer	Nat toevoer, mech afvoer	Nat toevoer, mech afvoer	Mech toe, mech afvoer zonder WTW	Mech toe, mech afvoer zonder WTW
Koelsysteem	geen	geen	geen	geen	geen	geen	geen
Regeling	vertrekschakeling	vertrekschakeling	vertrekschakeling	vertrekschakeling	vertrekschakeling	veegpuls	veegpuls
licht W/m2	17	17	17	17	17	17	11
Energielabel basismethode	G	G	G	F	E	D	C
EI-basismethode	3,33	2,75	2,25	1,72	1,58	1,32	1,18

Figure 4.3: Reference buildings by ECN [60]

4.2.6. Conclusion

The figures in this section indicate the necessity of the renovation task. Especially the IEQ appears troublesome. The structural condition is generally good, leaving open the option of renovation. This section also sketches the magnitude of the renovation task, which is significant. Furthermore, building typologies present an indication of installation and architectural applications in school buildings. These present a solid foundation for the development of technical measure packages.

4.3. Legal boundaries for school building renovation

Several laws and decrees state demands for school buildings (Algemene Rekenkamer, 2016). This legal framework presents the minimum requirements for Dutch primary school buildings. An overview is presented in Table 4.4.

Table 4.4: Legal framework educational housing demand from laws and decrees

Law/Decree	Demands
Uitvoeringsbesluit voorzieningen in de huisvesting PO/VO [5]	Necessary surface area for school buildings [m^2/student]. Primary education: 3,5m^2/student + 70m^2 fixed foot.
Wet op het primair onderwijs [6]	School boards are obliged to use the school building 'properly'.
Bouwbesluit 2012 [4]	Demands regarding safety, health, usability and energy efficiency of school buildings
Activiteitenregeling Milieubeheer [3]	Stipulates energy saving measures that schools are obliged to take (only applies for school buildings with an electricity demand >50.000kW and gas demand >25.000m^3 ([3], Article 2.15).

For renovation, both the Activiteitenbesluit and Bouwbesluit requirements are compulsory for Dutch primary school buildings. The Uitvoeringsbesluit determines minimum requirements for new construction. The Wet op het Primair Onderwijs stipulates requirements for the use phase. Thus, for this research the Activiteitenbesluit and Bouwbesluit form the legal boundaries in the development of technical measure packages.

There are no stipulated budgets for school building renovation [73]. School boards and municipalities are expected to discuss renovation budgets together. The fact that school boards are responsible for the exploitation of school buildings results in split incentives when municipalities are asked to invest in renovation. Cost reductions are only experienced by school boards, making them the single party experiencing benefits from energy efficiency measures.

A significant percentage of Dutch primary schools does not comply with the ventilation demands stipulated in the Bouwbesluit [8]. But, there is little enforcement of these demands [97]. An important reason why school buildings do not comply with these minimum demands, is the fact that the standard budgets for the construction of new school buildings is not sufficient to comply with the minimum standards from the Bouwbesluit. The costs to construct a school building according to the bare minimum standards in the Bouwbesluit are compared with the standard budget in Figure 4.4. The recovering construction market reinforces this trend, because of increasing construction costs.

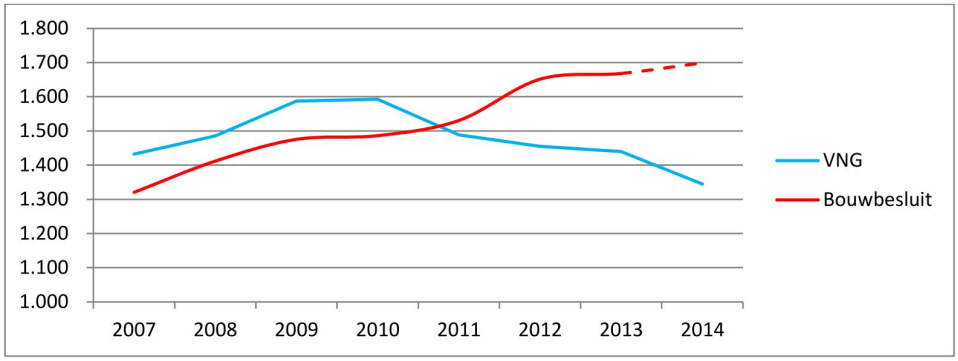

Figure 4.4: Growing gap between VNG standard budget and construction costs to comply with the Bouwbesluit [13]

This combination of negligence in complying with laws and decrees on one hand and the complication in financing a compliant school building on the other hand, results in an increasing gap between the minimal demands for school buildings and the actual school buildings. The technical measure packages should comply with these building requirements.

4.4. Decision-making on sustainable renovation

Many stakeholders are involved in the renovation of school buildings. From the top down, governmental agencies stipulate the aforementioned laws and decrees, as well as budgets and subsidies. From the bottom up staff, students and parents influence the decision-making process. This section provides insight in the responsibilities and interests of these stakeholders. It investigates conflicting perspectives and interests in the renovation of Dutch primary school buildings. These conflicts result from the organizational structure and the interests of stakeholders. Furthermore, this section shows how to cope with stakeholders depending on their interests, power and attitude towards sustainability renovation. As supplementary, an interview with a housing expert provides insight from practice on, among others, the decision-making process.

4.4.1. Organizational structure

Financial streams

Public finance directed at primary school buildings are separated in two streams. The first stream is purposed for the construction of new school buildings. This stream starts at the Ministry of Internal Affairs (IA), which determines the size of the municipal funds for every municipality in the Netherlands. This fund is called the VNG (Vereniging Nederlandse Gemeenten) standard budget. Municipalities assign a portion of this funds to construction and large adjustments of primary school buildings.

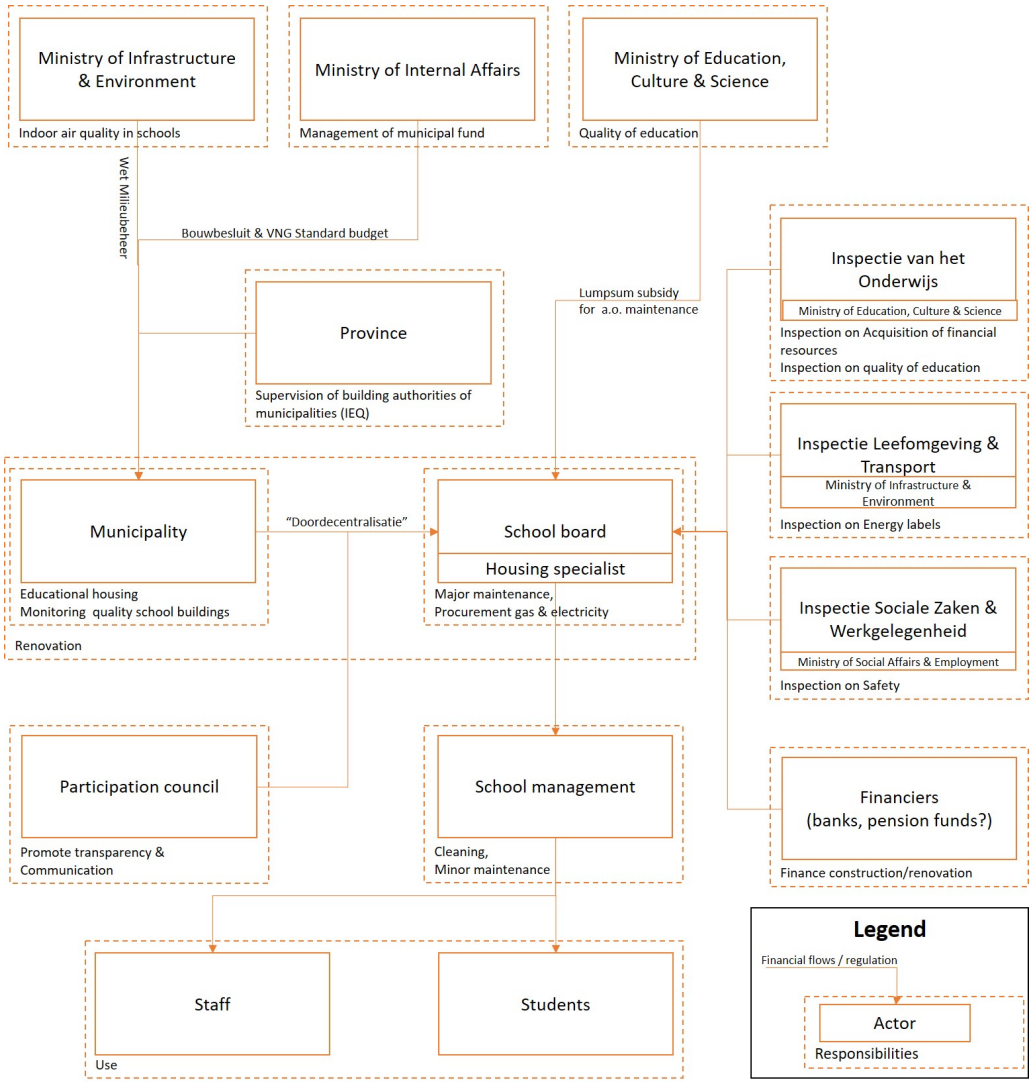

Figure 4.5: Organizational structure for the construction & maintenance of Dutch primary school buildings

The second stream starts at the Ministry of ECS, who assigns lump sum subsidies directly to school boards. These subsidies should cover the maintenance costs and small improvements of school buildings. Since the

1st of January 2015, this also includes maintenance of the building shell. The amount of the lump sum subsidies are determined by the number of students. For each student, primary schools receive €6.500 per year [75]. School boards are free to determine how they allocate this budget. Little is regulated regarding school building-renovation in the Bouwbesluit, e.g. nothing is mentioned about responsibilities [97]. In practice, it comes down to the municipality and school board to negotiate about responsibilities and budgets for renovation. The PO-raad, VO-raad, and VNG have submitted a proposal to capture legal renovation responsibilities [46]. In this proposal, renovation with a life-time extension of 25 years or more is considered the responsibility of the municipality, minus the measures that are already stipulated in the maintenance plan. This proposal is considered by the state secretary of ECS, and is currently under development [25]. The organizational structure is visualized in Figure 4.5.

Responsibilities

The ministry of IA is responsible for the management of the municipal fund [74]. The quality of education is the responsibility of the ministry of ECS. These tasks are for a large part fulfilled through the aforementioned financial streams. Provinces are responsible for the supervision of municipal building authorities ([8], p. 32). The following responsibilities in relation to school buildings lie with municipalities [71]:

- Replacement
- Construction
- Expansion
- Temporary construction
- Construction errors
- Damage repair of exceptional circumstances
- Property tax

After grant by the municipality, school boards become legal owner of the school building, municipalities remain economic owner. This means that if the school is lifted, the building is transferred to the municipality for free. Construction of new buildings by school boards is prohibited by the 'Investeringsverbod', because the lump sum subsidy they receive has the sole purpose of maintenance. Municipalities can move the responsibility for new construction to school boards through 'doordecentralisatie' ([8], p. 36). In this case, the municipality provides school boards with a budget for the development of a new school building. School boards are not allowed to add money from the lump sum subsidy to this budget [8]. Additionally, municipalities must monitor the quality of school buildings and are financially responsible for the property tax. School boards are responsible for the costs of major maintenance, which includes [71]:

- Indoor maintenance,
- Outdoor maintenance & adjustments,
- Responsive recovery maintenance,

School boards are responsible for major maintenance and the procurement of gas & electricity. Larger school boards often have housing specialists or directors, with specialist housing knowledge. Smaller school boards do not have such specialist knowledge. In some cases, school boards consist of parents, in other cases of employees. This indicates diverse ways schools can be organized. Cleaning and minor maintenance is generally assigned to school management. Participation councils are established to promote transparency and communication by school boards. Finally, teachers and pupils are end-users of school buildings and experience the results of renovation in terms of IEQ.

Monitoring agencies

There are several agencies monitoring the state school buildings: Inspectie van het Onderwijs, Inspectie Leefomgeving & Transport, and Inspectie Sociale Zaken & Werkgelegenheid [8]. These inspection agencies are part of the Ministry of ECS, Ministry of I&E, and Ministry of Social Affairs & Employment (SAE) respectively. The Inspectie van het Onderwijs oversees the quality of education and the lawful acquisition and use of funds by school boards. Their role in the inspection of school buildings is limited. The Inspectie van Leefomgeving & Transport oversees whether school buildings have a mandatory energy label. The inspectie Sociale Zaken & Werkgelegenheid inspects the safety in school buildings.

4.4.2. Stakeholder perspectives

Each stakeholder experiences sustainability renovation of school buildings differently. Given their responsibilities, they develop specific interests. For example, school boards are responsible for financing major maintenance. It is therefore in their best interest to keep maintenance costs low. Additionally, each stakeholder experiences different thresholds, that withhold them from renovation, and incentives, that stimulate them for sustainability renovation. The stakeholder chart in Table 4.5 presents an overview of these stakeholder perspectives.

Table 4.5: Stakeholder chart with thresholds and incentives for sustainability renovation

Stakeholder	Responsibilities	Interest	Threshold	Incentives	Power, role(s)
Ministry of Education, Culture & Science (ECS)	Determination of lump sum subsidies, final responsibility on quality of education	High, Qualitatively good education	Other priorities (e.g. teacher salaries, learning materials)	Student performance improvements	++, financier of lump sum subsidy
Ministry of Internal Affairs (IA)	Management of the municipal fund, determination of bouwbesluit legislation	High, Low municipal costs	Renovations could initiate municipal investment	Municipal investment could be lower in case of renovation instead of new construction	++, financier (subsidies), legislator
Ministry of Infrastructure & Environment (I&E)	Indoor air quality in school buildings, enforcement activiteitenbesluit milieubeheer	High, Good air quality in school buildings	-	Air quality improvements	++, legislator activiteitenbesluit milieubeheer
Inspectie van het Onderwijs	Inspection execution on quality of education	Medium, Qualitatively good education	Other priorities (e.g. teacher salaries, learning materials)	Student performance improvements	+/-, inspection
Inspectie Leefomgeving & Transport	Inspection on energy labels	Medium, Make sure all school buildings have an energy label	-	Energy label improvements, renovation could make schools examine their energy label	+/-, inspection
Inspectie Sociale Zaken & Werkgelegenheid	Inspection on safety	Medium, Safe school buildings	-	Safety improvements	+/-, inspection
Province	Supervision of building authorities in municipalities	Low, Good indoor climate in school buildings	-	Indoor climate improvements	+/-, supervision
Municipality	Financing new construction	High, Good educational housing, low construction & renovation costs	High initial costs, no financial benefits	Sustainability goals (e.g. energieakkoord)	++, policy maker, financier, economic owner
School boards	Major maintenance, gas & electricity procurement	High, Low renovation & exploitation costs, focus on small scale, flexibility	Distrust in market, cost contribution instead of total costs for municipality (new construction), other priorities (e.g. teacher salaries)	Exploitation cost reduction, better health & performance teachers & students, reduction of sick-leave, sustainable image	++, initiator, financier, legal owner

Housing specialist	Housing policy & management	High, Low renovation & exploitation costs, focus on small scale, flexibility, utilize knowledge from market and other schools, sufficient budget for housing	Distrust in market, cost contribution instead of total costs for municipality (new construction)	Maintenance cost reduction	++, internal specialist/expert
School management	Minor maintenance & cleaning	High, Minimal maintenance (costs), focus on small scale, flexibility, quality of housing	No complaints about quality of school buildings [97], other priorities (e.g. staff salaries)	Maintenance costs reduction, better performance teachers & students, reduction of sick-leave	+/-, manager
End-users (staff & students)	Building use	High, Good indoor climate	No complaints about quality of school buildings [97], other priorities (e.g. learning materials)	Better indoor climate, reduced health & performance impact, new building-layout for educational purposes	+/-, end-user
Participation council (Medezeggenschapsraad)	Promote transparency and communication	High, Insight & influence in school board policy	Other priorities (e.g. learning materials)	Better learning and work condition for end-users	+, supervisor of school board
Housing consultant	Consulting school boards in renovation	High, Perform tasks against minimal costs	-	Market position	+, external specialist
Contractors	Execution of renovation works	Low, Perform tasks against minimal costs, work-packages vs. extra work, scale of projects	Projects are too small scale	Market position, profits	+, executor
Financiers (banks, pension funds, investors)	Possible financing of renovations	Low, Increase scale of projects, lower risks, increase profits	Projects are too small scale	Sustainable image, profits	+, financier
Energy Service Companies	Installation and maintenance of energy installations	Low, High energy demand, large scale projects	Reduction of energy demand means reduction of market, small scale projects	Market position, profits	+, executor, owner, maintainer

Conflicting perspectives and interests

The stakeholder chart provides some important contradictory perspectives and interests. First, unclear regulation regarding the financing of renovation is problematic. Without clear financial responsibilities neither school boards nor municipalities are keen to invest in renovation. For school boards, there are financial incentives to improve school buildings, as it lowers their exploitation costs. Municipalities should be incentivized by the 'energieakkoord voor duurzame groei' [72] to increase energy efficiency of school buildings. This agreement aims to reduce the average energy use by 1,5% yearly, save 100PJ in 2020, increase the share of renewables to 14% in 2020 and 26% in 2023 and create at least 15.000 jobs. Yet, renovation initiatives are not flourishing without clear responsibilities. Both school boards and municipalities want to keep costs as low as possible. Without clear responsibilities in renovation, it comes down to the willingness of municipalities to contribute to renovation. This is very dependent on the political colors in the municipal administration as well as the relationships between school boards and the municipality. Split-incentives in renovation complicate this relationship, because municipalities do not experience (financial) benefits from sustainability measures in school buildings.

Second, school boards prefer to focus renovation projects on single school buildings, contractors and financiers prefer large scale projects. A benefit of small scale projects is that projects remain manageable for school boards and solutions can be tailor-made for the specific school to for example develop a flexible building. While large scale projects could introduce economies of scale, lower risks and increase profitability. The latter is preferred by financiers and contractors. This contradiction of interests results in unwillingness by financiers and contractors to participate in small renovation projects and unwillingness by school boards to scale up projects.

Another issue is that school boards want to use knowledge from the market, i.e. contractors. Yet, there is a certain level of distrust towards market parties, mostly because they are commercial parties aiming to maximize profits. It is in their interest to perform their tasks against minimum costs, possibly endangering quality. This distrust is fed by bad experiences, where products and services were offered cheaply, but did not meet promised expectations [97].

Finally, according to RVO research [97], school management and teachers are not complaining about the quality of school buildings. Which is strange given the poor state of school buildings. This reduces pressure on school boards to invest in their buildings.

4.4.3. Power-interest relations

These conflicts show that the stakeholders are interrelated. They can be classified based on their power, interest and attitude in improving the sustainability of primary school buildings. To image the stakeholder situation, a power-interest-attitude grid is presented in Figure 4.6. This three dimensional stakeholder presentation was first introduced by Murray-Webster & Simon [55]. The positions of stakeholders in this grid follow from the stakeholder chart (Table 4.5). The attitude is determined by their thresholds and incentives for sustainability renovation. Stakeholders with strong incentives and weak thresholds are expected to have a positive attitude towards sustainability renovation, weak incentives and strong thresholds result in a negative attitude.

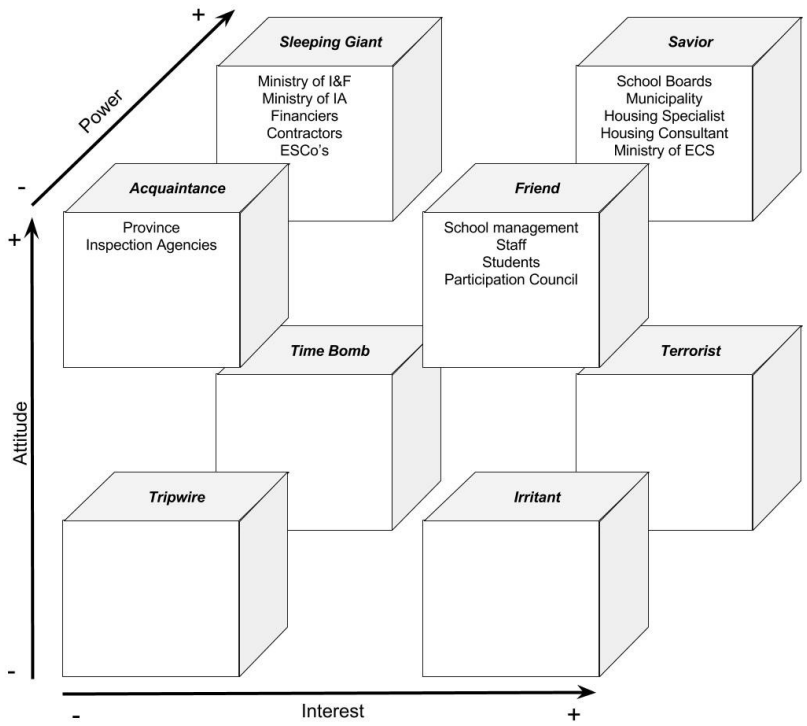

Figure 4.6: Power-Interest-Attitude grid

The power-interest-attitude grid shows that none of the stakeholders have a negative attitude towards sustainability renovation. Mostly because of indoor climate improvement, reduction of exploitation costs and a sustainable image. This indicates that the ambitions of stakeholders are generally well-aligned and that the problem for sustainability improvements does not lie within stakeholders' sustainability ambitions.

Sleeping Giants

This stakeholder analysis identifies five so-called 'Sleeping Giants'. These stakeholders, with high power, positive attitude and low interest, are underutilized potentials in school building renovation and "need to be engaged in order to awaken them" [55]. If their interest can be increased, they could become 'saviors'. The interests of the ministries of IA and I&E are difficult to increase, because their core responsibilities do not entail education specifically. Therefore, their interests function as is treated as a system boundary for this research. To increase the interest of financiers, contractors, and ESCo's, opportunities need to be presented that increase the scale of renovation projects. This makes such projects more interesting, because of higher returns and lower risks for both parties. Such stakeholders can be awakened by presenting financial opportunities that engage with these stakeholders.

Friends

Furthermore, it is important to keep 'Friends' close. School management, staff, students and participation councils should be involved in the renovation of school buildings, by using them as a sounding board [55]. This enables them to influence the way the school take shape after renovation. Their main concerns are to improve the IEQ in school buildings.

The decision flowchart can be used as a tool in the discussion with these stakeholders. This allows the discussion to be more substantiated and more concrete, given the additional insight it could provide both sides in the decision-making process in renovation. Furthermore, the effects of measures on IEQ and of IEQ on health and performance can arm these stakeholders in these discussions to steer towards IEQ improvement.

Acquaintances

The province and inspection agencies (acquaintances) need to be kept informed [55].

Saviors

The core stakeholders, or 'Saviors', are school boards, municipalities, housing specialist and consultant and the ministry of ECS. It is important to fulfill the needs of these stakeholders [55]. As mentioned earlier in

this section, conflicting perspectives and interests complicate alignment between these stakeholders. The perspective of the ministry of ECS is assumed a given in this research and function as is treated as a system boundary for this research.

4.4.4. Insights from practice

As supplementary information, an interview is held with an educational housing expert: Frank Rubel, educational housing and facility employee and member of the PO Raad (Primary Education Council). This provides additional information from practice, that cannot be found using desk research. Such as the reasons for renovation, the service life and decision-making process. The findings from this interview are presented below.

Reasons for renovation

Rubel [76] describes the general reasons for school building as follows:

1. The building does not comply with today's demands in terms of indoor climate or exploitation costs.
2. Growth or shrinkage of student numbers
3. New education systems demanding architectural alterations

The structural condition of the buildings is an important aspect. Some buildings in Rubel's portfolio are over 100 years old, but are in such condition that renovation is a very suitable alternative. Other buildings are 'only' 40 years old, but in such poor condition that new construction seems the only alternative. Buildings that are designated as monuments, only apply for renovation. Replacement of specific building parts or installations is generally not a reason for renovation. Such cases are stipulated as minor maintenance.

Rubel gives an example for a reason for renovation. One of the school buildings in his portfolio is experiencing major shrinkage. Based on the student numbers, they are only entitled to slightly more than half of the building surface area. The superfluous areas are in use by other parties such as childcare, general social work, speech therapy and a pediatrician, offering many additional services. In case of new construction, they lose square meters, and these parties need to find a different location. Or these parties need to contribute in costs, what most of them are not willing. Renovation is the only way to keep these parties within the building.

Decision-making process

To describe the decision-making process, Rubel [76] indicates that in practice, the decision-making process is very organic and case specific. He provides two examples.

In the first example, there was shrinkage in student numbers and the empty areas are used by other functions, such as childcare, a center for youth and families and a pediatrician. One of the first decisions was between new construction, or renovation. In case of new construction, the school would lose in surface are, losing the additional users of the existing building. Or they would need to participate in financing the new building, but in this case many parties quickly fall off. Therefore, renovation was chosen. Then the demands for the new building were drafted, and the costs to comply with these demands were stipulated.

The second example, a 'small' adjustment evolved into a series of adjustments, and eventually renovation. From these adjustments, a cost indication was drafted. Then they considered how these costs can be financed with the municipality.

From these two examples, a generic, high-level decision-making process is drafted (see Figure 4.7). This process is a high-level representation of the 'Process to be flowcharted'. The reason for renovation can be very diverse, but when renovation is considered, this process can be walked through. After exploring the existing situation, the desired new situation is drafted. Then, the means and costs are determined to reach this desired situation. And finally, the way of financing is determined.

Figure 4.7: Decision making process

Property management cycle

This section explores how the decision making process relates to the service life planning process of school buildings. Through desk research a preliminary process cycle was found (see Appendix B, Figure B.1). After minor adjustments (Figure B.2), this process cycle is used as a basis for discussion with Rubel [76]. This resulted in the property management cycle presented in Figure 4.8. The service life planning process can be divided in five main phases: strategy making, renovation initiation, decision modeling, decision-making and implementation.

The strategy making phase involves the information collection of the school building and setting up strategies for the building renovation. In a 'Meerjarenonderhoudsplan' (MOP), school boards stipulate maintenance expectations for their school buildings for a specific period. For this purpose, a condition measurement is performed of the buildings every 3 years [76]. The MOP's of the school buildings are used to form a municipal 'Integraal huisvestingsplan' (IHP). In this plan, the municipality together with school boards determine when and what school buildings need renovation or new construction. This way both the school board and municipality are better prepared for these projects and the decision-making process should be accelerated.

If the exploitation costs of a school building become too high, the indoor climate is insufficient, there is exceptional growth or shrinkage, or the building does not comply with the educational system the MOP and IHP are put side by side. This is the start of the renovation initiation phase. If the school building is eligible for renovation, together with the municipality the renovation budget can be determined. If not, the school board need to renegotiate financial arrangements. This phase is described as the renovation initiation. Next, the ambitions for the school building renovation are determined in a PoR (Program of Requirements). Such ambitions can be formulated using e.g. Frisse Scholen, GPR-gebouw, Energielabels or Kwaliteitskader Onderwijshuisvesting.

During the decision modeling phase, the opportunities for renovation are examined. These opportunities involve technical measures, organizational opportunities and financing forms. The opportunities are then valuated to enable substantiated comparison.

The decision-making phase starts with the selection of renovation opportunities. Followed by the organization of the project. This involves tenders and contractor selection. Finally, in the implementation phase the renovation is executed and the results are evaluated. Evaluation and the sharing of evaluation results between school boards happens too little [76].

Given the abovementioned description from Rubel [76], the following property management cycle is drafted Figure 4.8. This cycle enables us to connect the property management cycle with the decision-making process described above.

With this overview of the decision-making process and property management cycle it is possible to determine where the decision flowchart can engage and assist in the decision making process. This is determined when the designs are tested by school boards.

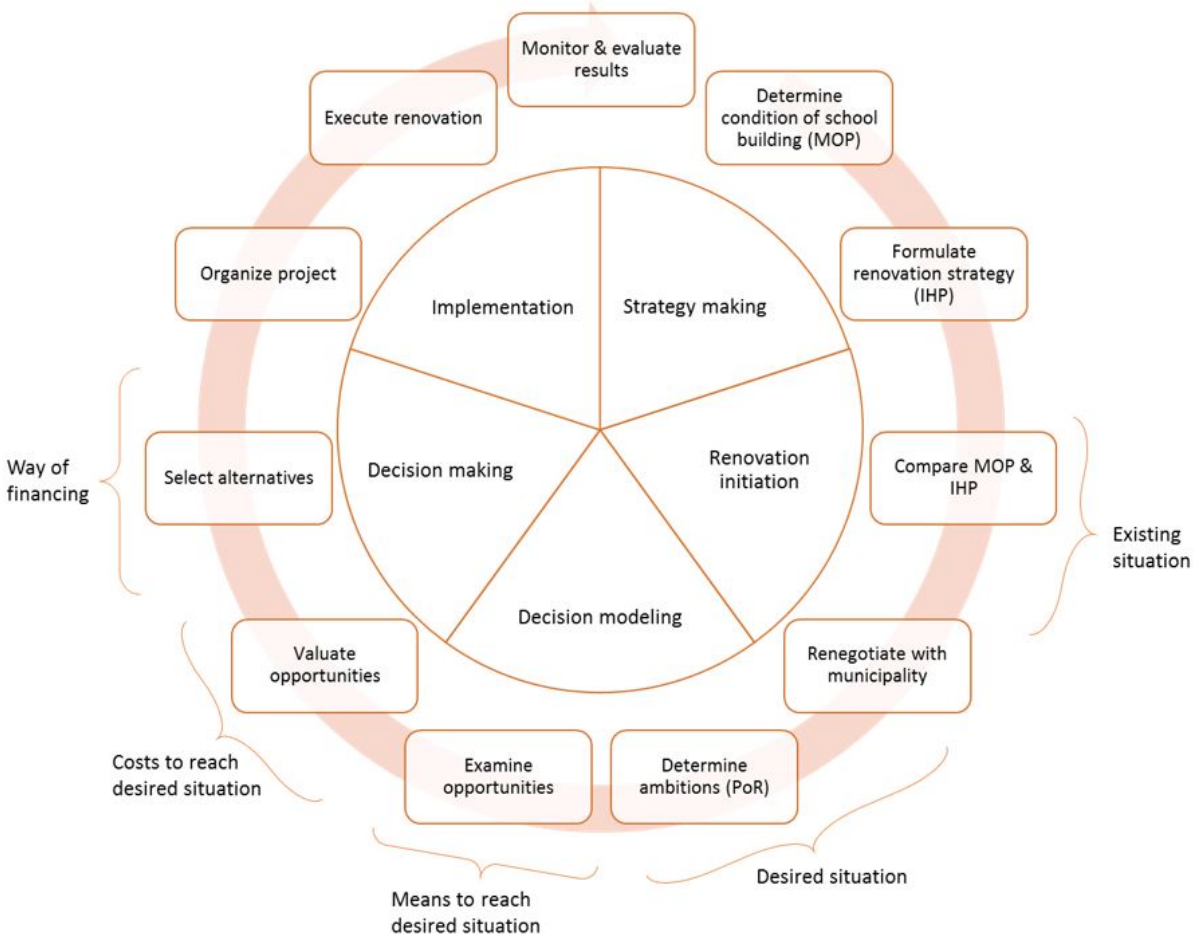

Figure 4.8: Property management cycle for school building renovation

4.4.5. Conclusion

From this elaboration on stakeholders, responsibilities and decision-making process, the following conclusions are drawn.

Key players in the renovation issue for primary school buildings are: school boards, housing specialists/consultants and municipalities. Between school boards and municipalities, indistinctness in responsibilities are an issue. Furthermore, several 'Sleeping Giants' are identified: financiers, contractors and ESCo's. If the interests of these players in primary school renovation can be increased, they become key players as well. But, for this issues of scale and trust need to be overcome.

The decision-making process in Figure 4.7 presents the high-level decision-making process in the renovation of school buildings. This process represents the 'Process to be flowcharted'. The property management cycle in Figure 4.8 presents the cycle school boards continuously walk through. By linking these processes, it is possible to identify where the decision flowchart can engage and be of use.

4.5. Barriers in sustainability renovation of primary school buildings

From the organizational in the previous section, conflicting interests are identified that form barriers for the development of sustainable primary school buildings. This section explores more barriers, divided in four categories: technical, financial, organizational, and knowledge barriers. These barriers represent underlying reasons for the situation described in the situation sketch (section 1.1) and current state of the Dutch primary building stock (section 4.2).

4.5.1. Technical barriers

As mentioned in the situation sketch, indoor environmental quality is often underexposed in the development of a program of requirements by school boards. They often emphasize energy efficiency measures, not knowing how this might affect IEQ. This section explores adverse effects of sustainability measures. Furthermore, it presents a series of sustainability measure packages from which lessons can be drawn for the development of new sustainable measure packages.

If sustainability is associated solely as a trade-off between energy efficiency improvement and cost reduction, results can be counterproductive. For example, by insulating a school building, thermal losses and the energy demand for heating is reduced. Yet, the amount of fresh air that enters the building through infiltration reduces simultaneously, affecting the indoor air quality if active ventilation is low. IEQ improving measures can be counterproductive as well. These trade-offs are generally known as the energy efficiency-thermal comfort-indoor air quality dilemma (EE-TC-IAQ dilemma) [14]. Although the EE-TC-IAQ dilemma considers only the effects between thermal comfort, indoor air quality and energy efficiency, this research additionally considers the effects on lighting and noise comfort. Several studies are conducted on the relation between energy efficiency and IEQ measures. Several conflicting measures, described by Persily & Emmerich [66] is given in Table 4.6.

Table 4.6: Conflicting sustainability measures [66]

Aim of measure	Reduced ventilation	Effect	Affected factor
Energy efficiency	Reduced ventilation	Molds	Air quality
Energy efficiency	Increased thermal insulation	Increased likelihood of condensation (potential biological growth)	Air quality
Energy efficiency	Increased cooling efficiency	Increased humidity levels (potential biological growth)	Air quality

Without knowledge about the adverse effects measures can have, the overall balance between People, Planet and Profit can deteriorate. A problem with IEQ is that these effects are difficult to substantiate [76], where energy performance is easily determined through the energy bill. The effects of poor IEQ can be assigned to other causes, e.g. lack of sleep, bad health or physical condition instead of the state of the building. It is therefore important to consider these conflicting measures in the renovation of school buildings to ensure proper balance between People, Planet and Profit.

Another technical issue occurs in the exploitation period. The use, maintenance and tuning of installations greatly affects the performance and lifetime. This is generally poorly managed in the school buildings, because such knowledge is often not present at schools [73]. It is important to mention this, so school boards take note of it.

4.5.2. Organizational barriers

Section 4.4.1 elaborates how the primary education housing system in the Netherlands is organized. This structure is one of the underlying causes for the barriers to renovate school buildings. This section explores additional barriers that result from desk research.

First, the current maximum requirements in the building regulations function as minimum requirement [73]. CO_2 concentrations are stipulated to be 1200 ppm at maximum, yet school buildings are designed to barely comply to this criterion while running on full capacity. This way the minimum requirements are easily exceeded in practice, when the circumstances are not perfect.

Second, inspection of school buildings leaves much to be desired [97]. There are no standard inspections after construction or renovation that check the performance of school buildings. Complexities, mostly in mechanical ventilation systems, can result in poor maintenance of ventilation channels, causing bad air quality [73].

Third, as already mentioned in the organizational structure, there is no regulation that stipulates responsibilities in the renovation of school buildings [73, 97]. Rijksbouwmeester [73] also indicates that there is no clarity in who is, in the end, responsible for the IEQ. Such unclarities further complicate renovation initiatives.

Fourth, also identified from the organizational chart, many school boards indicate that they do not want to commit themselves to long term contracts [82]. They see long term contracts as juridical risks, which they are not willing to take, reducing the solution space for contractual arrangements.

Finally, a large lack of trust towards market parties is apparent. Promises made in the past by market parties about energy efficiency and financial benefits have not been met. School boards' perception of market parties is that their sole aim is profit, making them distrustful. This is found back in a large distrust in the results of sustainability measures (39%) [82].

The first two issues cannot be tackled by school boards directly. Such issues should be handled by governmental agencies. For the third issue, school boards can actively engage in negotiations with the municipality to allocate responsibilities. The commitment to long-term contracts and trust towards market parties are issues that should be covered in the development of the decision flowchart. Either opportunities need to be found that take away these issues, or they should at least be considered.

4.5.3. Financial barriers

The financial situation for school boards is cramped. Given recent budget cuts, this will remain so for the time being. Knowing that IEQ is one of the first things that suffers from budget cuts, the People dimension is at risk. This section explores the barriers that make financing of school building renovation difficult.

The height of budgets and financial streams are a frequently mentioned problem [73]. This is underlined by school boards themselves [82]. 82% of the interviewed school boards underline the fact that budgets are insufficient.

Ruimte-OK & Klimaatverbond Nederland [82] held consultation sessions with school boards, whom mention several other financial barriers. A large majority (78%) misses guarantees, making the financial risks of improving sustainability too high. Difficulties in financing sustainability measures is often mentioned (70%), accompanied by the disability to attract credit (63%). These issues can be explained by the fact that the market prefers large scale projects, while school boards prefer tackling one building at a time. Finally, many school boards believe that sustainability measures could have adverse effects on exploitation (62%).

School boards really struggle with the financing of renovation projects. It would be lucrative to close the gap between external financiers and school boards. To do so, the differences in interests and perspectives as described in section 4.4 need to be overcome.

4.5.4. Knowledge barriers

The fourth barrier category is that of knowledge. As mentioned before, school boards are no developers, and therefore often lack knowledge about renovation projects. The underlying reason for lack of knowledge is the lack of professionalism in renovation management [73, 97].

There is much fluctuation in the extent to which school boards perceive themselves able to evaluate the supply market [82]. This is strengthened by fragmentation in the supply market [97]. In the consultation sessions with Ruimte-OK & Klimaatverbond Nederland [82] school boards indicate a lack of knowledge in several aspects. 73% does not have sufficient insight in the financing possibilities, 70% cannot make decisions independently about lifetime extension measures for their school buildings, and 56% has no insight in their energy use and energy saving possibilities.

65% of the consulted school boards indicate that they have other priorities than improving the state of the school building. This links closely with the expectation expressed at the end of the introduction; if school boards would be aware of the positive (and negative) influence indoor climate could have on the performance, productivity and health of students and teachers their attention might shift more towards IEQ improvements.

This lack of knowledge and experience is felt in the development of a program of requirements for renovation [73]. They are searching for ways to set up an integral approach, and to maintain a certain degree of flexibility for the building and standardization of solutions.

4.5.5. Insights from practice

According to Rubel [76] the main barrier for the renovation of school buildings is definitely money. For the ability to finance renovation, school boards depend on municipalities. In such cases the relationship with the municipality is important. If their relationship is good, the municipality is more prepared to make financial

contributions. But even more decisive is the composition of the municipality. If political parties are represented with education high on the agenda, they are more willing to contribute in school building renovation.

Additionally, Rubel [76] indicates that insight in the way sustainability can be earned back would be very helpful in making considerations whether measures are worth the investment. Also, exploitation costs are difficult to determine. Rubel [76] explains: if you want to install PV-panels on the roof, but your roof could need renovation in 10 years. Then the PV-panels need to be removed before and put back after renovation. What would this mean for the costs? If such decisions could be better informed, it would improve the decision-making process.

In general, sustainability is more attractive for school boards than municipalities [76]. This can be explained by the fact that school boards experience the financial benefits from sustainability improvements. But, national and local climate goals can instigate municipalities to invest in sustainability. Also, the composition of the school board itself can be decisive. Some boards are more familiar with architectural adjustments than others, if so, they usually prefer architectural changes more.

4.5.6. Conclusion on barriers

This section indicates the adverse effects certain technical measures can have and the importance of proper use, maintenance and tuning of installations. Furthermore, it identifies two important organizational barriers for the s; proneness to long-term commitment and lack of trust towards market parties. As well as several financial and knowledge barriers, which indicate that there is a need for more insight in financing and technical opportunities. Also, the need for guarantees is an aspect to consider in the decision flowchart. The barriers derived from desk research are confirmed by an expert from practice. The financing problems and insights in technical measures and their effects are mentioned specifically.

4.6. Opportunities in school building renovation

The previous section identifies barriers that withhold school boards and other actors to renovate school buildings, or that make them renovate school buildings poorly. This section focuses on opportunities that enable school boards to organize and finance renovation, and guide them towards renovated school buildings with good People, Planet & Profit balance. The section is divided in technical, financial, and organizational opportunities.

4.6.1. Technical opportunities

To determine the technical measures that make school buildings more sustainable, existing sustainable measure packages and lists are discussed. Some pros and cons of these measures are presented, based on own interpretation, and conclusions are drawn regarding the usefulness of information provided by the packages and lists. Then, a list of measures is drafted, that serves as input for the new technical measure packages. Necessary information about these measures is gathered using desk research. This serves as input for the development of the new sustainable measure packages.

In this section, several sustainable measure packages and lists are discussed. Along each list/package the effects on energy efficiency and IEQ, based on interpretations by Van Bueren et al. [92] and Duurzaam MKB [53], are presented. These effects are determined qualitatively and presented in Appendix A.

Erkende maatregelen Activiteitenbesluit Milieubeheer

The 'acknowledged' measures prescribed in the Activiteitenbesluit Milieubeheer [42] are measures that are earned back within 5 years. Schools with an electricity demand over 50.000 kW and gas demand over 25.000 m^3 are obliged to apply these measures ([3], Article 2.15). Although only 15% of primary schools falls within this requirement, they cover 44% of the total surface area of all Dutch primary schools [97].

Table 4.7: Pros and cons of the Erkende maatregelen Activiteitenregeling Milieubeheer

Pros	Cons
- Short payback periods, or 'quick wins' - Both energy efficiency and IEQ improving measures	- No insight in investment costs and/or savings - No insight in what situation measures are applicable/useful

Sustainability measures by RVO

The list of sustainability measures by RVO [102] is very extensive and therefore only a section of it is presented in Appendix A. Apart from architectural measures, this list also presents behavioral and managerial measures.

Table 4.8: Pros and cons of the sustainable measures by RVO

Pros	Cons
- Effects of measures on energy efficiency and IEQ.	- No guidance in when measures are applicable.
- Both energy efficiency and IEQ improving measures.	- No investment costs and savings.
- Insight in payback periods	

Cost efficient energy saving packages by ECN [60]

ECN's packages present the most cost-efficient energy saving measures. The packages are based on the existing energy label of a school building (Table 4.9). Based on this label, technical measures are picked from a predefined list. For each package, investment costs, savings and payback period are presented.

Table 4.9: Pros and cons of the cost efficient energy saving packages by ECN [60]

Pros	Cons
- Insight in investment costs and savings.	- These packages only present measures to reach energy label C.
- Clear initial situation and desired situation.	- Many schools have no insight in their energy label, thus using energy label as input can be inconvenient. - No improvements in IAQ. - Savings presented in €/m^2, expectation is /year, but not specified. - Only applicable for school buildings with energy label G, F, E or D. - No "quick wins" (<5 year payback time) included

Sustainable measure packages by Arcadis [10]

The sustainable measure packages by Arcadis [10] are used to determine the investment costs and payback periods to reach a predetermined energy label (Table A.4, A.5 & A.6). The model determines the current energy label based on the year of construction of the building. Based on this energy label, measure packages are proposed. The building periods with corresponding energy labels, according to this model, are presented in Table 4.10.

Table 4.10: Energy labels per building period [10]

Building period	<1994	1995-2002	2002-2007	>2008
Energy label	G	F	E/D	C

Table 4.11: Pros and cons of the sustainable measures by Arcadis [10]

Pros	Cons
- Insight in investment costs and savings. - Clear initial situation and desired situation. - Applicable for almost all school buildings. - Both energy saving and IEQ improving measures.	- No "quick wins" included.

4.6.2. General reflection

In general, the sustainable measure packages and lists provide useful information for sustainability renovation of primary school buildings. From these existing packages, several positive aspects are considered in the development of new measure packages:

1. Use building periods as input. Under 10% of the school buildings has an energy label [99]. Building periods are generally known. Therefore, building periods should be used instead of energy labels. But, make sure to consider already completed renovations.
2. Provide insight in the effects on energy efficiency, IEQ, payback period, investment costs and savings are interesting for school boards.
3. Include quick wins. Not all school boards (can) have high sustainability ambitions. Some just want to comply with legislation, or prefer quick paybacks.
4. Include both energy efficiency and IEQ improving measures.

4.6.3. List of applicable sustainable measures

To include quick wins, the measures as stipulated in the Activiteitenbesluit Milieubeheer [3] are included in the list of measures. Some of these measures are combined or simplified. Measures such as: LED outdoor lighting, LED indoor lighting, LED advertising lighting, are bundled under LED lighting. Furthermore, the measures presented in the existing packages are included, along with some new measures. Namely, draught-proofing, outdoor shading, heat-cold storage (WKO), and isolation of ventilation ducts. The reasons for adding these measures are as follows and result from desk research. Sustainable procurement of energy is not included in these measures, because it does not improve the quality of the building, even though it does not negatively influence the IEQ of the building.

- Draught proofing is improving the air tightness of a building, by sealing cracks along doors, windows or other openings. This reduces loss of heat in winter, and reduces drafts. It is important to make sure that draught-proofed buildings have good ventilation, because the amount of fresh air entering the building through infiltration reduces drastically.
- Outdoor shading reduces the need for cooling in summer, thermal comfort, and glare entering the building. This way both the energy demand and IEQ are improved.
- Heat-cold storage enables a building to store cooling water in an aquifer and can save up to 40-80% in energy use compared to conventional cooling [52].
- Insulating ventilation ducts reduces heat losses during ventilation, improving energy efficiency without affecting IEQ.

Additionally, the following information is provided each measure:

- Investment costs, (Exploitation costs are not included, because these are very building and user specific. It is not considered feasible to present generic exploitation costs.)
- Payback period,
- Effects on energy efficiency & IEQ,
- And fiscal measures & subsidies (Note: only private institutions are entitled to these measures, thus only applicable for school boards if the measures are taken by e.g. an ESCo),

The costs per measure follow from an actualization report investment costs by Arcadis [10]. The costs taken from this report are presented as 'initiële kosten'. Because these costs estimations are presented in varying units, these costs are multiplied by a factor. This factor represents an indication of the amount of floor area per square meter of another surface area. The calculations are presented in table 4.12. The surface areas are derived from a reference building presented by BDB Bouw(kosten)data [13], based on minimum requirements by the Bouwbesluit [4].

Table 4.12: Determination of surface area factors [13]

Surface area	Abbreviation	m_2	%	Factor
Bruto vloeroppervlak	BVO	1312	100	1
Gebruiksoppervlak	GO	1180	90	0,9
Netto bebouwd oppervlak	NBO	737	57	0,57
Netto geveloppervlak	NGO	879	67	0,67
Open geveloppervlak	OG	308	24	0,24
Netto dakoppervlak	NDO	781	60	0,60

The payback periods are retrieved from the database behind the Arcadis technical measure packages (Table A.4, A.5 & A.6) and a database of energy saving tips; Duurzaam MKB [53]. The qualitative effects on IEQ are determined using Van Bueren et al. [92] Duurzaam MKB [53], and Boerstra et al. [15]. The possible fiscal benefits are retrieved from Duurzaam MKB [53]. The measures presented in Figure 4.9 form the basis in the development of sustainable measure packages.

Maatregelpakketten PO		Kostenberekening						Effect maatregelen op:				
									Binnenmilieu			
Thema	Maatregelen	Kosten	Eenheid	Factor	Initiële kosten	Eenheid	TVT [jaar]	Energie	Luchtkwaliteit	Temperatuur	Licht	Geluid
Isolatie	Spouwmuur* (Rc = 4,5)	€ 64	€/m² BVO	0,67	€ 95	€/m² NGO	5	+		+		+
	Buitengevel (Rc = 4,5)	€ 110	€/m² BVO	0,67	€ 164	€/m² NGO	10	+		+		+
	Dak (Rc = 6)	€ 64	€/m² BVO	0,60	€ 108	€/m² NDO	25	+		+		
	Vloer (Rc = 3,5)	€ 19	€/m² BVO	0,57	€ 33	€/m² NBO	15	+		+		
	Kierdichting	€ 19	€/m² BVO	0,90	€ 21	€/m² GO	5	+		+		+
	HR++ beglazing (U-waarde = 1,2)	€ 37	€/m² BVO	0,90	€ 41	€/m² OG	15	+				+
	Isolatie ventilatiekanalen	€ 5	€/m² BVO	0,90	€ 6	€/m² GO	10	+				+
	Isolatie warmteleidingen*	€ 1	€/m² BVO	0,90	€ 1	€/m² GO	5	+	+			
Ventilatie	Tijdschakeling ventilatie*	€ 1.200	€/stuk	1,00	€ 1.200	€/stuk	5	+	+			
	Cascaderegeling ventilatie*	€ 4.500	€/stuk	1,00	€ 4.500	€/stuk	5	+	+			
	(indien mech. toe-en afvoer) Warmteterugwinning ventilatie*	€ 36	€/m² BVO	0,90	€ 40	€/m² GO	5	+	+	+		
	(+WTW) Mechanische toe- en afvoer (in aantal lokalen)	€ 12.500	€/lokaal	-	-	-	-		+			
Verwarming & Koeling	Weersafhankelijke regeling aanvoer verwarming*	€ 1	€/m² BVO	0,90	€ 1	€/m² GO	5	+				
	Weersafhankelijke regeling opstarttijden verwarming*	€ 1	€/m² BVO	0,90	€ 1	€/m² GO	5	+				
	HR107 ketel*	€ 25	€/m² BVO	0,90	€ 28	€/m² GO	5	+	+	+		
	Buitenzonwering	€ 16	€/m² BVO	0,24	€ 70	€/m² OG	5	+		+	+	
	Warmtepomp (inlc. Radiatoren op LTV)	€ 111	€/m² BVO	0,90	€ 123	€/m² GO	10	+		+		
	WKO	€ 90	€/m² BVO	0,90	€ 100	€/m² GO	7	+				
Verlichting	Veegpulsschakeling*	€ 1	€/m² BVO	0,90	€ 1	€/m² GO	5	+				
	Aanwezigheids- + daglichtdetectie	€ 5	€/m² BVO	0,90	€ 5	€/m² GO	5	+				
	LED verlichting*	€ 5	€/m² BVO	0,90	€ 5	€/m² GO	5	+			+	
Opwekking	Zonnepanelen per m2	€ 255	€/m²	1,00	€ 255	€/m²	10	+				
*Erkende maatregelen Activiteitenregeling milieubeheer.												
Let op: installaties hebben een beperkte levensduur (15-20 jaar). Levensduur en werkbaarheid is sterk afhankelijk van het gebruik, onderhoud en inregeling.												

Figure 4.9: Sustainable measure list

4.6.4. Financial opportunities

Ruimte-OK [82] drafted a comprehensive overview of financing opportunities. The five main alternative ways to finance renovation: by own means, borrowing, renounce ownership of installations, third party funds and renounce ownership of real estate. Additionally, some recent developments are mentioned. This section provides a brief description of each way of financing. Note that the ways of financing do not exclude each other, combinations are possible.

For the decision flowchart, it is important to understand the considerations that determine what financing form suits a specific situation. For this purpose, the pros and cons, as described by Ruimte-OK [82], of each form of financing are formulated in tables. The opportunities should present ways to cope with the organizational barriers identified in section 4.5.2, by presenting ways to increase project scales, cope with split-incentives, and take into account the lack of trust towards market parties and proneness to long term contracts.

By own means

This first form of financing is most straight forward. Financing by own means comes down to saving up money before spending it on renovation. Money can be kept apart from the lump sum subsidy that is intended for maintenance. But it is often the case that the lump sum subsidy is not sufficient to keep up maintenance, let alone safe extra for renovation. This is very dependent on the year of construction and the size of the building. On average schools experience a shortage on maintenance of €10.000 per year [38].

Borrowing

School boards can borrow funds in many ways. Ruimte-OK [82] describes the following:

1. Schatkistbankieren. A way of borrowing is through so called 'Schatkistbankieren'. In this form, school boards can borrow from the Ministry of Finance against a very low interest rate. Because school board need to keep all public funds at the ministry, their ability to spend money is limited.

2. Commercial banks. Fund can also be borrowed at commercial banks. Yet, commercial banks demand higher securities and a complete, substantiated business plan. This asks for much preparation, with the risk of not receiving the loan.

3. Bank Nederlandse Gemeenten (BNG). School boards can also borrow from the 'Bank Nederlandse Gemeenten'. This governmentally established bank asks lower interest rates that commercial banks, but also requires a complete business plan. An almost certain condition is municipal guarantees.

4. Municipality. Highly dependent on the availability of finance and political situation in the municipality, but some municipalities provide loans. Such loans generally provide lower interest rates than commercial banks.

5. Fonds Volkshuisvesting. The fonds Volkshuisvesting is a revolving fund characterized by a very low interest rate. This form of borrowing is very dependent on the municipality, who must be a member of the fund and approve that the funds are used for educational housing instead of residential housing.

6. Suppliers. It is possible to borrow from suppliers. They then pay a continuous compensation for e.g. installations.

7. Groenfinancieren. Some 'green funds' provide finance for projects with a 'green' character. Often extra 'green' actions are requested for such funds.

Table 4.13: Pros & cons of borrowing forms

Borrowing form	Pros	Cons
Schatkistbankieren	Low interest rates	All public funds at Ministry, Limited freedom of spending, Municipal guarantee
Commercial banks	Financing terms are negotiable	Fully substantiated business plan required, Municipal guarantee or third-party liabilities required
Bank Nederlandse Gemeenten	Low interest rates	Fully substantiated business plan required, Municipal guarantee is required, Large projects
Municipality	Low interest rate, Favorable financing terms	Risk for municipality-school board relationship
Fonds Volkshuisvesting	Very low interest rate	Not appropriate for small financing, Municipal approval to invest in educational, instead of residential, housing
Suppliers	No use of own means	Long term commitment with supplier, Ongoing fee can be higher than a loan
Groenfinancieren	Favorable financing terms	A 'groenverklaring' is required

Temporarily renounce ownership of installations

The benefits of renouncing ownership of for example installations is that the liquidities of school boards are not affected and the possibility to use the latest techniques. Yet, the financial charges are generally higher than in other financing forms.

1. Vendor lease. In this case, a good/building is sold to the bank and leased back by the school board.
2. Renounce ownership at the supplier. School boards can lease products or installations from a supplier in the form of a 'financial' or 'operational' lease. In this case, the product remains property of the supplier.
3. Rent and rent/sale. School boards can also rent products or installations from a supplier, with an arrangement that over time, the product is sold to the school board.
4. ESCo's. Energy Service Companies install, maintain and manage installations on behalf of school boards. School boards do not invest in the installations, but pay the costs with interest. In the contract arrangements energy performance is stipulated.

Table 4.14: Pros & cons of renouncing ownership

Ownership form	Pros	Cons
Vendor lease	Possible for new as well as existing goods	-
Relinquish ownership at the supplier	-	Long term commitment with supplier
Rent and rent\sale	-	Not possible to maintain latest technologies, Long term commitment with supplier
Escos	-	Unclear market information, Often focus only on energy efficiency, possibly at the expense of IEQ

Third-party funds

The fourth financing category is attracting finance from third parties. In this case, no payments or investments are necessary. These measures usually contribute little.

1. Subsidies. Subsidies are generally public money supplied for a specific purpose. Certain requirements must be met to grant the subsidy.
2. Sponsoring. Some companies are willing to invest in schools. In return, they experience brand awareness.
3. Crowdfunding. With crowdfunding, funds can be supplied by e.g. parents or locals.
4. Fiscal measures. Through certain fiscal measures, costs can be lowered. Examples are the Energie Investeringsaftrek (EIA) and Milieu Investeringsaftrek (MIA). Side note is that these fiscal measures only apply for private parties. This means that if school boards invest themselves, they are not eligible for these measures.

Table 4.15: Pros & cons of third-party funds

Third-party funds	Pros	Cons
Subsidies	-	Extensive financing terms
Sponsoring	-	Often limited financial contribution
Crowdfunding	-	repayment obligation
Fiscal measures	Can be used with a lease construction	Company tax must be paid, Profits need to be made

Renounce ownership of real-estate

School buildings can be sold to investors, and leased back by the school board. In this construction, housing tasks are moved to the investor. Municipal cooperation is necessary to renounce ownership, along with the participation of multiple schools. This form of financing is not necessarily cheaper because risk coverage and returns for the investors are included in the rent.

4.6.5. Organizational finance opportunities

Apart from these 'common' forms of financing, some new innovative ways are under development that present new ways to organize finance.

1. Investment fund for educational housing. This initiative aims to assign all housing tasks under one party, an (investment)fund. This should increase efficiency and thus cost reductions.
2. PPP-structure. In such a structure, the municipality and school boards, accompanied by market parties together form a private company. This ensures that the measures, expertise and risks are shared. Such a partnership asks for long-term commitment.
3. Beheersstichting or Cooperation model. In a Beheersstichting school boards together form a foundation, of which they are owner. School boards together bear the responsibility for the organization and investment for their educational housing In a cooperation-model, the school boards remain owner of their building. This way they share both risks and benefits.
4. 'Huren als eigenaar' [27] or sale and lease back. In this model, Stichting Maatschappelijk Vastgoed (SMV), sets up a separate foundation that acts as landlord. The school building becomes property of the foundation. The renovation is entirely financed by a bank, with municipal guarantee. The school board leases the building from the foundation for a predetermined rent. The responsibilities for maintenance and renovation are for the foundation.
5. Bundeling scholen in een DBFMO prestatiecontract [27]. In DBFMO contracts a contractor or consortium designs, builds, finances, maintains and operates the building. By bundling multiple buildings in one contract, such projects become interesting for market parties. Because one party is responsible for all tasks, costs are optimized over an agreed period.
6. Cooperation with other parties. Cooperations with other parties can be organized in order to make more efficient use of the building. Either though simultaneous use, if parts of the building are empty. Or through use at different times, e.g. childcare after school hours.

Table 4.16: Pros & cons of organizational finance opportunities

Organizational form	Pros	Cons
Investment fund for educational housing	Could lead to economies of scale	Loss of housing management, Loss of decision-making freedom, Loss of ownership building
PPP-construction	Execution and risk allocated to private company, Use of third party expertise	Long term commitment with third parties, Loss of decision-making freedom
Beheersstichting or Cooperation model	Shared risks, Shared benefits, Loss of decision-making freedom	
'Huren als eigenaar' or Sale and lease back	School boards can focus on core tasks, Constant rent charges	Loss of housing management, Loss of decision-making freedom
DBFMO-contract bundling	Increased attractiveness for investors	-
Cooperation with other parties	The other users pay part of the rent	Limited freedom, because the other parties have to be taken into account in making building-related decisions

4.6.6. Input from expert meetings

The experts notice a distinction between common financing and organizational opportunities and innovative financing and organizational opportunities. This distinction is mainly apparent in the fact that common opportunities are proven and repeatable, where innovative opportunities are not. According to the experts, innovative opportunities should be mentioned, but should receive less attention than the common opportunities. This way, school boards are aware of the distinction and can decide whether they want to apply a common or innovative way of financing. Additionally, some ways of financing do not work accordingly in practice. These should be left out entirely. The third-party funds generally form no significant contribution, and should therefore be left out. Fiscal measures are only applicable in private investments, and should therefore be linked to ESCo's.

The common financing opportunities are own means, borrowing and energy service companies. The following opportunities generally do not apply in practice, according to experts:

- Groenfinancieren
- Relinquish ownership at the supplier
- Rent and rent/sale
- Investment fund for educational housing
- 'Huren als eigenaar'

The remaining organizational finance opportunities are stipulated as innovative organizational forms. The Investment fund is still in its initiative phase, and can therefore not be applied yet. PPP-construction and DBFMO-contract bundling are organizational forms that appear not to work in practice and are therefore left out.

5
Designs

The previous chapter presents the foundation for the development of the designs. The technical barriers and opportunities determine what aspects should, and should not, be included in the technical measure packages. The financial and organizational barriers present important aspects to consider in the decision flowchart. The opportunities present feasible outcomes from the decision flowchart. This chapter presents how the findings from desk research are applied in the designs.

5.1. Sustainable measure packages

Following the identified barriers and opportunities, sustainable measure packages are developed. The barriers indicate measures that are harmful for the IEQ in a school building. The opportunities indicate what aspects from existing sustainable measure packages and lists should be included. Also, some additional sustainable measures are presented. The sustainable measure packages are provided in Table 5.1.

Given the energy label-related building typologies described in section 4.2.3, the packages are divided over three building periods: <1975, 1975-1992, and >1992. For each building period, three payback period based packages are presented:

1. Basic package
   Based on measures that are paid back within 5 years, comprising of the acknowledges measures from the Activiteitenbesluit Milieubeheer [3]. In case of the oldest buildings, it is not possible to comply with the Bouwbesluit by applying measures that are paid back within 5 years.

2. Energy & Cost efficient package
   This package includes measures that are paid back in 15 years, and includes the basic package with the following additions; façade insulation instead of cavity wall insulation, floor insulation, draught proofing, HR++ glazing, insulation of ventilation ducts, balanced ventilation with heat recovery, outdoor shading and the HR107 boiler is replaced by air based heat pumps.

3. Energy neutral package
   This package includes measures that are paid back in 25 years, and is similar to the Energy & Cost efficient package, with the following additions; roof insulation, the air based heat pump is replaced by heat pumps combined with heat cold storage, mechanical in- and outlet ventilation, and PV-panels.

Costs

The total costs are expressed in two items: investment costs per m^2 gross floor area and additional investment costs. Most measures are housed in the former cost item. Time switch ventilation, cascade control ventilation and PV-panels cannot be calculated back to €/m^2 gross floor area using a factor. These are determined a piece and per m^2 PV-panel, then totaled per building. To determine the total investment costs, the investment costs per m^2 gross floor area are multiplied by the gross floor area of the school building, plus the additional investment costs. After this, the investment costs are included a 21% VAT (Value added tax).

Additionally, an example of the average Dutch primary school building is provided. This includes a school building with a surface area of 1.300 m^2 and 8 classrooms (size of an average Dutch primary school building [86]). This presents a quick insight into the extent of the total investment costs of the packages.

IEQ effects

The effects of the measures are defined qualitatively. Only positive effects are presented. If a buildings' fresh air supply is very dependent on infiltration, draught proofing could lead to worsened air quality. These effects are very dependent on the building specifics, and therefore only function as an awareness tool. The effects are determined based on views by Bueren et al. [92] and DuurzaamMKB.nl [53].

5.1.1. Assumptions

For the other building periods, similar packages are presented. Some measures are left out, because school buildings dating from these periods are expected to already have these measures since construction [60]. The following assumption are made in the development of the technical measure packages:

- Since 1975, newly built school buildings are equipped with cavity wall insulation [53].
- Since 1992, newly built school buildings are equipped with mechanical in-and outlet [60].
- Heat recovery is only applicable in combination with mechanical in- and outlet ventilation.
- Since 1975, newly built school buildings are equipped with HR boilers [60].
- Since 1992, newly built school buildings are equipped with time switch lighting [60].
- Presence + daylight detection is considered a replacement for time switch lighting [53].

5.1.2. Frisse Scholen performance

The measure packages are scored based on the Program of Requirements Frisse Scholen [100]. For each specified theme, the Frisse Scholen Klasse is determined for a school building, after applying the proposed package. Some requirements are formulated in such a way that it is not possible to determine the Frisse Scholen Klasse given the generic character of the packages and because they are very dependent on the building. E.g. requirements about the amount of daylight or artificial lighting are dependent on the size of windows and number of light points. Such requirements are very building-specific. Therefore assumptions are made. The results of this Frisse Scholen Klasse evaluation is presented in Figure 5.1.

Energy

Regarding the Energy theme, the Frisse Scholen PoR, presents requirements on the thermal resistance (R_c) of the building insulation. For existing buildings, the R_c-value of closed parts (roofs, façade and floors) should be 1,3 m^2K/W at minimum to comply with Klasse C. Klasse B requires compliance with the minimum requirements for newly built schools stipulated in the Bouwbesluit [4]. This entails an R_c-value of 3,5 m^2K/W for floors, 4,5 m^2K/W for facades and 6,0 m^2K/W for roofs. As these values are aimed for by the insulation measures, buildings comply with Klasse B after application of all the insulation measures. In the Basic packages, no insulation measures are taken. This means that, given the building typologies provided in Figure 4.3, buildings from the period <1975 that apply the basic package do not comply with Frisse Scholen Klasse C. From 1975 onwards, school buildings already comply with Klasse C in terms of insulation requirements. The Energy & Cost efficient packages do take insulation measures. Yet, roof insulation is not included in this package, due to the long payback period. Therefore, applying the Energy & Cost efficient package, will not ensure Klasse B. The energy neutral package does comply with the insulation requirements.

Also requirements regarding the efficiency of installations are included. Balanced ventilation systems must have an efficiency of 60% along with time scheduling to comply with Klasse C. An efficiency of 75% along with CO_2 scheduling is required for Klasse B. The balanced ventilation measure complies with the latter. The efficiency of the heating system is set at 90% for Klasse C and 95% for Klasse B. For cooling, outdoor shading and *'free cooling'* (zomernachtventilatie) are required.

Air quality

The CO_2 concentration of class rooms, during operational hours, cannot exceed 1.200 ppm for Klasse C and 950 ppm for Klasse B. The application of balanced ventilation is assumed to be sufficient for Klasse B. Also requirements are included regarding the height of the ceiling. The maximum height is 2,6 m for Klasse C and 2,8 m for Klasse B. Buildings from the period 1975-1992 are characterized by low ceilings [83]. It is therefore assumed that these buildings will not comply with the ceiling height requirements for Klasse B.

Thermal comfort

The temperature requirements stipulate, among others, a minimum and maximum operational temperature and maximum velocity. Because heat pumps are included with low temperature heating radiators, the thermal comfort increases. The application of heat pumps is assumed to suffice for Klasse B.

Noise comfort

Frisse Scholen stipulates maximum noise levels for different areas of a school building. It is assumed that insulated buildings (from R_c-value >1 m^2K/W) comply with Klasse B, and non-insulated buildings (R_c-value <1 m^2K/W) with Klasse C.

Lighting

Lighting requirements stipulate a minimum illumination intensity of 300 lux for Klasse C and 500 lux for Klasse B. It is assumed that the implementation of LED lighting is sufficient to comply with Klasse B. This is the case for all packages.

Maatregelpakketten PO														Effect maatregelen op:				
		<1975				1975--1992			>1992					Binnenmilieu				
		5 jaar	15 jaar	25 jaar		5 jaar	15 jaar	25 jaar	5 jaar	15 jaar	25 jaar							
Thema	Maatregelen	1.1 Minimum Activiteitenbesluit	1.2 Energielabel C Frisse Scholen B	1.3 Energielabel B Frisse Scholen B	1.4 Nul-op-de-Meter	2.1 Wettelijk minimum	2.2 Energielabel C Frisse Scholen B	2.3 Energielabel B Frisse Scholen B	3.1 Wettelijk minimum	3.2 Energielabel C Frisse Scholen B	3.3 Energielabel B Frisse Scholen B	Energie	Luchtkwaliteit	Temperatuur	Licht	Geluid
Isolatie	Spouwmuur* (Rc = 4,5)	1										+		+		+
	Buitengevel (Rc = 4,5)		1	1			1	1		1	1	+		+		+
	Dak (Rc = 6)			1				1			1	+		+		
	Vloer (Rc = 3,5)		1	1			1	1		1	1	+		+		
	Kierdichting		1	1			1	1		1	1	+		+		+
	HR++ beglazing (U-waarde = 1,2)		1	1			1	1		1	1	+				+
	Isolatie ventilatiekanalen		1	1			1	1		1	1	+				+
	Isolatie warmteleidingen*	1	1	1		1	1	1	1	1	1	+	+			
Ventilatie	Tijdschakeling ventilatie*	1	1	1		1	1	1	1	1	1	+	+			
	Cascaderegeling ventilatie*	1	1	1		1	1	1	1	1	1	+	+			
	(indien mech. toe-en afvoer) Warmteterugwinning ventilatie*								1	1	1	+	+	+		
	(+WTW) Mechanische toe- en afvoer (in aantal lokalen)		8	8			8	8					+			
Verwarming & Koeling	Weersafhankelijke regeling aanvoer verwarming*	1	1	1		1	1	1	1	1	1	+				
	Weersafhankelijke regeling opstarttijden verwarming*	1	1	1		1	1	1	1	1	1	+				
	HR107 ketel*	1				1						+	+	+		
	Buitenzonwering		1	1			1	1		1	1	+		+	+	
	Warmtepomp (inlc. Radiatoren op LTV)		1	1			1	1		1	1	+		+		
	WKO			1				1			1	+				
Verlichting	Veegpulsschakeling*	1	1			1	1					+				
	Aanwezigheids- + daglichtdetectie			1				1			1	+				
	LED verlichting*	1	1	1		1	1	1	1	1	1	+			+	
Opwekking	Zonnepanelen per m2			300				300			300	+				
Kosten	Investeringskosten per m^2 Bruto Vloeroppervlak (incl. BTW)	€ 117	€ 393	€ 584		€ 40	€ 393	€ 584	€ 52	€ 436	€ 628					
	Aanvullende investeringskosten (incl. BTW)	€ 6.897	€ 127.897	€ 220.462		€ 6.897	€ 127.897	€ 220.462	€ 6.897	€ 6.897	€ 99.462					
	Terugverdienperiode in jaren	5	15	25		5	15	25	5	15	25					
Voorbeeld investeringskosten: PO school met opp. 1.300 m^3 BVO (8 lokalen)		€ 159.250	€ 639.105	€ 979.984		€ 59.278	€ 639.105	€ 979.984	€ 74.851	€ 573.318	€ 915.612					
Frisse Scholen thema	Energie	-	C	B		C	C	B	C	C	B					
	Lucht	-	B	B		C	C	C	C	B	B					
	Temperatuur	C	B	B		C	B	B	C	B	B					
	Geluid	C	B	B		B	B	B	B	B	B					
	Licht	B	B	B		B	B	B	B	B	B					

*Erkende maatregelen Activiteitenregeling milieubeheer.

Let op: installaties hebben een beperkte levensduur (15-20 jaar). Levensduur en werkbaarheid is sterk afhankelijk van het gebruik, onderhoud en inregeling.

Figure 5.1: Sustainable measure packages

5.2. Decision flowchart development process

To assist school boards in choosing technical packages, a decision flowchart is developed. This flowchart guides them through a series of questions, leading to the opportunities identified in Section 4.6. The goal of this flowchart is to provide school boards insight in the opportunities of school building renovation and provide structure to their decisions. By providing this information they should be able to initiate well-financed and -organized projects, with more attention towards IEQ improvement in school building renovation, leading to an improved People, Planet, Profit balance. This section presents the development process of these versions. The described versions of the flowchart are presented in Appendix E.

5.2.1. Decision flowchart version 1

Based on desk research and the first two expert meetings, an initial draft of the flowchart is developed (Figure E.1). This draft is used as a basis for the third expert meeting, with the aim to reflect and build upon this work. Key findings from these expert meetings are presented in Appendix C. The decision flowchart structure follows from the decision-making process described in paragraph 4.4.4.

Flowchart structure

The top part of the flowchart determines the existing situation using the building period of school buildings. The desired situation is expressed by three sets of technical measure packages per building period. At this stage, the packages were not developed yet, but present a first indication of means necessary to reach a desired situation. These packages present an indication of investment costs, and thus the necessary funds to reach the desired situation.

The bottom part of the flowchart starts after the investment costs for the measures are identified, and determines the way of financing. The considerations follow from the pros and cons of the financing and organizational measures presented in 4.6.4 and 4.6.5.

The opportunities consider the conflicting perspectives presented in section 4.4.2. Some innovative organizational opportunities present ways to cope with split incentives and introduce a Total Cost of Ownership (TCO) approach. Others present ways to increase the scope of projects. Some opportunities do require long term commitment to a contract and trust towards market parties. By presenting other opportunities school boards are able to consider whether these issues are determining their choice.

5.2.2. Decision flowchart version 2

Following the third, and final expert meeting, the flowchart is altered, resulting in the second version of the flowchart (Figure E.2). Main changes to the flowchart are the addition of a legend, where supplementary information is presented. Additionally, the findings from Table 4.1 are presented across the flowchart, as notions to emphasize the importance of IEQ in terms of productivity, performance, health and costs.

This version is used to in qualitative interviews with school boards and in the focus group. The results from these tests are presented in Chapter 6.

Flowchart structure alterations

The top part of the flowchart is expanded. Considerations are added about the horizon of the proposed intervention, and the ambition level for the school building. Furthermore, the names of the technical measure packages are changed to present sustainability ambitions:

In contrast with the top part, is the bottom part simplified, because according the attendees in the second expert meeting, the financial opportunities should be more structured. The financial means are distributed in five categories:

1. Own means
2. Municipal funds
3. Loans
4. Energy Service Companies
5. Innovative organization forms

Also, several financing and organizational opportunities are left out, as described earlier in section 4.6.6.

6

Results

The designs are presented to several school boards and market parties. School boards are approached separately and review the designs in a semi-structured interview. Market parties are brought together in a focus group. With input from these experts, the designs were altered, and tested again by two school boards and a member of a municipality by ways of qualitative interviews. This chapter presents this process and key findings from it.

6.1. Results from the focus group

A focus group was organized to reflect on the designs. This enabled the attendees to directly respond to each others comments. Discussion among the attendees could instigate new ideas about the flowchart and corresponding technical packages and how it could improve its workability. Here the findings from this focus group are presented and summarized. But, first the attendees are presented.

6.1.1. Attendees

Unfortunately, not all the invited people were able to attend the focus group. The following people did attend the focus group:

- An associate at NLII (Nederlandse Investerings Instelling).
- A senior advisor at NIA (Nederlands Investerings Agentschap).
- A senior advisor utility buildings specialized in education at RVO.
- Sector leader education at Arcadis.

6.1.2. Key findings

In general the decision tree is in line with the vision of the NLII, says Jelle Postma. In their vision, they aim to create more demand for sustainability improvement in educational housing, to accelerate renewal of the existing building stock. Making school boards aware of the possibilities, the way this flowchart does, can contribute to this purpose. Regarding the structure and substance of the decision flowchart they gave useful comments.

Jelle Postma and Dick Hagoort notice the division in the flowchart. The top half, represents the technical part and has a clear decision flowchart structure. The bottom half, representing the financing and organizational part, is more informative than decision oriented. They advice to structure the bottom half in such a way that it is similar to the top half in terms of structure. Also the top half focuses on single buildings, while the bottom half can be applied for both single buildings and building portfolios. It would be useful to make the top half also applicable for building portfolios. This way the flowchart can facilitate in upscaling projects.

Some comments address the language used in the flowchart. The term 'horizon' is rather vague. They advise the use of a more simple, straightforward question. Also the names of the packages are not comparable, these should be similar.

In the bottom half, funding, financing and organization opportunities are used interchangeably. But there is a difference between these types of opportunities. Funding are e.g. own means and governmental subsidies, and is free of charge. Financing is generally through a third party, and must be paid back in due time. Organizational opportunities are ways to organize responsibilities for example to ease finance or execution of the project.

Additionally, several opportunities are missing. First, some forms of loans are missing. These are opportunities that have been removed earlier, because according to the expert meeting attendees, these do not add significant value and do not apply in practice. The financial experts think they do, and therefore should be added. Furthermore, a new fund by Rabobank should be added [78]. Also, the NLII initiative should be added by the time this is developed.

The possibility of adding a sample calculation was discussed, that shows a comparison between keeping the responsibility for renovation and maintenance at the school boards and unburdening the school boards of these tasks. This could provide insight in the benefits of unburdening. It is necessary to show the calculations, to create a sense of trust among school boards. Given their lack of trust towards market parties, such calculations should be transparent and backed by independent organizations such as RVO and Ruimte-OK. The NLII will consider the possibilities of developing such examples.

Finally, the presentation of the sustainable packages was considered unclear. This raised a discussion about how much information needs to be presented. Some argue that only the costs, payback period and Frisse Scholen performance are relevant, and therefore only these should be shown. Others point out the need for transparency, again because of the distrust towards market parties. If school boards see what measures are included in the packages, they are more likely to accept the costs of the packages.

Conclusions

- Division between the top (technical) and bottom (financial & organizational) half of the flowchart
  - Bottom half should be more decisive instead of informative
  - Top half should be applicable for portfolios
- Break apart funding, financing and organization
- Include previously removed finance opportunities

6.2. Results from school board interviews

The initial plan was to also organize a focus group among school boards, but this did not work out due the holiday period at the time the designs need testing. Therefore, qualitative interviews are held to receive input from school boards on the designs and the effects they might have on the balance between People, Planet & Profit. This section introduces the interviewees and findings from the interviews.

6.2.1. Introduction of the interviewees

Jan Aalberts is director of operations at Spaarnesant. Spaarnesant is an independent foundation facilitating public primary education in Haarlem. Their portfolio consists of 26 schools in 30 buildings at different locations. The foundation comprises of approximately 800 employees, ranging from staff members to teachers. Aalberts [7] runs the staff bureau, which in turn supports the board and schools. 2 days a week his tasks involve educational housing.

As former policy officer of educational housing at municipalities, advisor and interim manager educational housing, operations and management, Aalberts [7] has plenty of experience in the educational sector. Educational housing is his major predilection in his work, and the reason why he and Spaarnesant are very active in this area. Along with their newly built energy neutral school, these are the reasons why his expertise is often called for by external parties. An example is his role as ambassador at the Green Deal Scholen.

A lot of money and effort is put in Spaarnesant's housing plan, in which they aim to make major improvements in their housing stock. Sustainability is an important aspect in these improvements, so far as it fits their (financial) capabilities. Because of the growth in Haarlem, they are experiencing growth in educational housing demand. This is in contrast with a major part of the Netherlands, where many schools experience shrinkage.

At Spaarnesant a clear division is apparent in their building stock. In the inner city, they have old, monumental buildings. These are in decent shape, but their functionality is poor. Ideally, Spaarnesant would like

to replace these buildings, but this is not an option given their monumental status. Sustainability and indoor climate is a challenge in these buildings. The other school buildings are 30-40 years old, and generally of poor quality. These schools are located in the outer areas in Haarlem and are earlier eligible for replacement. When Spaarnesant became independent in 2009, they received extra financial means, which enables them to actively renovate their building stock.

Robbert Jan Piet is a sustainability consultant for school boards with a long education background. From 1985-2010 he taught EU law at the HVA. For 10 years he was an alderman at the municipality of Heerhugowaard /Beverwijk, with the tasks of education, spatial planning and sustainability. Now, he is chairman of the supervisory board of Ronduit and is also in the national consultation of supervisors. Piet [67] thinks supervisors are an often underestimated group. School boards need get their decisions by their supervisors, before implementing them.

Ronduit provides primary education in Alkmaar and Heerhugowaard and special secondary education in 5 municipalities in Noord-Holland, noord. As supervisor he looks after the school board and is their strategic partner. Yet the board is the one who takes the decisions. In addition, he keeps up a network throughout the country for the school board. His focus is on educational housing, which is very rare. He only met one colleague with in a similar position.

Ronduit owns 20 primary education buildings, on average 40 years old. For years they have been the most sustainable school board in the Netherlands, without having sustainability as policy goal. They were able to take over many installations from an old installation company, which was very advanced in sustainability. This includes urban wind turbines, solar panels and heat-cold storage.

6.2.2. Key findings

This section presents several subjects that are discussed in the interviews. Every subject ends with an itemization of key findings. The interview questions used for these evaluative interviews are presented in Appendix D.

Way of and reason for renovating

Spaarnesant's way of renovating evolves around incorporating as many aspects as possible, within their means. Taking along every small aspect, results in the savings made. Quick wins will always be executed if liquidities are available. Also, the means by the municipalities are handled with care. An example is a school building that will be renovated, where the architect advised additional energy saving measures. The municipality offered the funds to finance these measures. But, Spaarnesant first hires an advisor to determine whether these measures are worthwhile. If not, they advise the municipality to use these funds on other school buildings.

In general, school boards are in favour of renovation, says Piet [67]. In the Netherlands, schools have approximately a third excess space compared to legal standards. They want to keep this excess, which can only be done through renovation. But, lack of clarification in legislation about renovation responsibilities is a real problem. The administrative complexity on both the side of the schools as the municipality is underestimated. The knowledge about educational housing in municipalities is also disappearing. Making it difficult for school boards to find someone to talk to. Therefore, in practice, school boards target new construction, because then responsibilities are clear.

- Renovation is preferred by school boards, yet unclear responsibilities complicate renovation to such an extent that they often choose for new construction despite their preference [67].
- Large scale one-off renovation is sometimes preferred above stepwise renovation, unless it includes quick wins [7].

The fact that school boards prefer renovation, is a sign that school boards would be interested in the opportunities of renovation. The sustainable measure packages facilitate both large scale, one-off renovation as well as quick wins.

Knowledge level on renovation of school buildings

Because his situation allows him to spend time and effort in educational housing, Aalberts' [7] knowledge level is advanced for a school board. In technical terms, he understands the important aspect, such as R_c-values and ppm, but he is no engineer. Regarding organizational and financial issues, he developed much knowledge and experience through attending presentations by e.g. Ruimte-OK.

Not all school boards are this fortunate. Educational housing is often something boards do alongside their core activities, making it difficult to develop knowledge and experience. Both Aalberts [7] and Piet [67] indicate that within municipalities, this knowledge and experience is disappearing. Therefore, knowledge of advisors is important. Yet for school boards it is difficult to judge the knowledge of advisors, for this they should use means presented by agencies like Ruimte-OK and Green Deal Scholen.

Piet [67] explains that many forget that school board members are people who in most cases started as teacher, and after training worked their way to school management and eventually to the board. He sees lack of knowledge, problem awareness, and power to get to solutions as the main problems in educational housing, instead of financing. Money is not always the problem. Heerhugowaard is a small municipality with little funds, but has always been a leader in sustainability. This was because they got subsidies from e.g. the EU and the Waddenfonds [104]. The question "how bad do you want it?", is important as it determines how much effort is put in finding the right solutions and partners and gaining knowledge.

- The interviewees possess much knowledge, but for the average school board this is not the case.
- Lack of knowledge is the main issue in educational housing [67]

The designs can provide a basic level of knowledge, partly tackling this issue.

Decision flowchart

Aalberts [7] thinks the flowchart provides useful guidance and recognizable considerations. E.g. the building periods develop an image about what buildings they include. Also, the financial opportunities are recognizable, mostly from presentations by Ruimte-OK and other institutions. Spaarnesant is reserved about these opportunities. Partly because they have sufficient reserves to finance renovation, and partly because schools need the municipality and warranties for such means. If a school board does not have such knowledge like Spaarnesant does, this flowchart is very interesting. It would be useful to look at it together with the municipality, as they are often critical in making decisions.

Aalberts [7] goes on stating that: The tool should use existing instruments, as there already exist so many. The tool should help simplify things and help make decision. In the consideration what to do with a building, this tool is useful. As there is a lot on this area, and this is simple enough, especially when it can be made digital. It will make school boards curious. It will not answer all questions, but will definitely be useful in making considerations, broadening view, and equipping and preparing school boards in conversations with advisors and contractors.

Aalberts [7] is rather sceptic about many of the financial and organizational opportunities. They often have only few success stories. And in practice many stakeholders are involved (multiple municipalities, school board, market parties), which puts up so much time and effort, that nothing comes of it, while the ideas are very promising in theory.

If a school board has a project at hand, and a tool for which little knowledge is necessary and several logical steps are followed, from which a general advice results, can provide useful insights, says Aalberts [7]. Its simplicity is its strength. The flowchart is especially helpful for so called 'eenpitters', which entails almost half of all Dutch primary school boards (but only 8% of the school buildings) [69], and during the initiation phase (Fig 4.8). 'Eenpitters' are school boards managing a single school.

Piet [67] believes that the decision flowchart fails in speaking the same language as school boards. Their business evolves around the quality of education. School boards need to be aware of the effect that their buildings have on the quality of education. Using this as starting point can evoke problem awareness. Furthermore, school boards generally reason from portfolio level, starting with the strategic housing policy. Also, he advices to work from a Total Cost of Ownership (TCO)-approach. Because this provides opportunities for a long-term vision. Finally, procurement is an important aspect. School boards are no experienced principals. If they would procure based on lowest price, the results could be bad. They should procure performance-based, this way they challenge the market to come with smart solutions.

Piet [67] also thinks that the decision flowchart can be an eye-opener for 'eenpitters', by showing them that they need to scale up. Furthermore, he states that the flowchart is 'interesting', but needs further development in using 'education language' by focusing on the quality of education.

- School boards can be sceptic about the workability of the opportunities, possibly due to the lack of trust towards market parties [7].
- The decision flowchart should use more 'education language' and a TCO-approach [67].

  - A TCO-approach is not always applicable in primary educational housing. It is very dependent on the organization, E.g. it is applicable in case of 'volledige doordecentralisatie'.

- Its simplicity makes the flowchart useful, especially for 'eenpitters' [7].
- The flowchart provides a basic knowledge level for talks with market parties [7].

These expectations show that the designs can provide additional knowledge. Yet the scepticism by school boards towards some of the opportunities is another hurdle. Additional information, presenting comparisons between the opportunities as discussed in the focus group, could take away this scepticism partly. Using 'educational language' is a good take-away.

Indoor environmental quality

The flowchart presents recognizable definitions such as energy labels and Frisse Scholen Klassen. This helps to understand what IEQ is about. In the end, it explains why IEQ is important and that it improves learning performance [7].

Aalberts [7] presents examples that indicate problems regarding IEQ. Spaarnesant measured the CO_2-levels in all their school buildings and mentioned this in their newspapers. Yet, no one ever asked what the results of these measures were. Also, no complaints were expressed by either parents, students or staff. Attention towards IEQ must come from the top down, because it does not come from below.

Another example was that of a rather new building (2004), where many people complained about headaches, not necessarily about poor IEQ. After many checks and improvements, the building had Frisse Scholen Klasse B, but still people complained. In the end, the issue was that there were no operable windows. Even though the IEQ was good, the psychological effect of having no operable windows, resulted in complaints about headaches. After actively promoting how good the IEQ actually was, complaints started reducing.

This presents two issues: IEQ needs to be supervised from above (by school boards), because bottom up initiatives will not come and operable windows are important for psychological effect.

Not everyone is aware of the importance of IEQ. It is therefore important to emphasize this. The students themselves do not care for the IEQ, but they are still entitled to a healthy learning environment. IEQ should be promoted to municipalities and school boards and nationwide to parents and teachers to make them aware of the consequences [7].

In many school boards IEQ still receives little attention. Spaarnesant offered other school boards to use their CO_2-meters for free, but none accepted due to lack of time and other priorities. ICT is a way more popular subject than housing, while proper housing also presents many benefits [7].

Piet [67] agrees that IEQ is a very important, underestimated subject. Partly because end-users, teachers and students, often do not experience the IEQ as bad. Also, the effect of behaviour on the IEQ is largely unknown and underestimated. The fact that school boards would do anything to improve the quality of education, needs to be used to create awareness of IEQ. The perception on quality of a school building by school boards is, according to Piet [67], currently only coupled to the marketing value of their buildings. A good building attracts more students.

- The flowchart presents useful, important insights in the effects of IEQ [7].
- The insights in IEQ help create problem awareness by school boards, which is currently an underestimated subject [67].

The attention to IEQ is appreciated by school boards and can guide them towards school buildings with better IEQ.

Conclusions

The flowchart is in line with the way school boards look at renovation. It provides ways to make renovation possible. It also presents ways to tackle the building in one go. The knowledge level of school boards is deemed poor by the interviewees and even perceived as the core issue in educational housing. This is in line with the goal of the decision flowchart to improve knowledge and insight. Using more 'education language' and a TCO-approach could improve the flowchart according to Piet [67]. Yet, a TCO-approach depends on the organizational structure of the housing responsibilities, and is therefore not always applicable. 'Education language' could be incorporated more. The implementation of IEQ is important and helps to create problem awareness.

6.2.3. Decision Flowchart version 3

This section presents the third version of the Decision Flowchart, following the input presented above (Figure E.3). Many small adjustments are made with respect to the flowchart presented in Appendix E. Only the major adjustments are discussed here. After these adjustments, this flowchart is again tested by a school board member, a school board director and a member of a municipality through semi-structured interviews. This enables an additional check upon this new version of the flowchart.

Package formulation

The technical packages are formulated differently. The 'Basis' package is changed to 'Wettelijk minimum'. This way it is instantly clear what the package is about and for what sustainability ambition. The 'Energiezuinig, kostenefficient & energiezuinig' package did receive positive feedback. But it does not present how energy-efficient, cost-efficient and healthy it is. Therefore the name of this package is changed in 'Energielabel C & Frisse Scholen B/C'. The third package, 'energieneutraal', tried to emphasize the ambitious character of this package. Yet, whether the package results in an energy neutral school building, cannot be ensured. Therefore, and to enable comparison with the second package, the name is changed to 'Energielabel B & Frisse Scholen B/C'.

Portfolio level

The top half only enabled the application of one school building, while the bottom half can be used for a portfolio of buildings. To smoothen this out, the top half needs to become applicable for portfolios. The new flowchart presents a question ending the top half, asking whether the school board wants to improve a single building, or a building portfolio. In case of one building, the flowchart can be followed as before, in case of a portfolio, the top half can be repeated for every building in the portfolio.

From informative to decisive

In the previous version, the bottom half did not provide guidance in the selection between financing and organizational opportunities. Therefore, this part is provided with additional considerations, guiding school boards through the decision-making process.

Differentiation between funding, financing and organization

The focus group indicates that the way funding, financing and organization of projects is applied is unstructured. This new flowchart tries to structure these different opportunities. First, funding opportunities are presented by ways of own means and municipal funds. If these are insufficient, third party financing options are presented. The organizational opportunities are presented after.

6.3. Results from the final design tests

This final design tests are conducted with a member of a school board, a school board director and a municipality. Again, semi-structured interviews will determine the workability of the decision flowchart and the qualitative expectations on the People, Planet, Profit balance in renovated school buildings.

Chantal Broekhuis is head of the Facility and Housing department at PCOU & Willibrord, comprising of 15 employees. PCOU & Willibrord manages 65 school buildings in 7 municipalities in total, and is one of the major school boards in the Netherlands. They are in good contact with the other major Dutch school boards. With over 9 years experience in her current function, Broekhuis [16] possesses a lot of experience in the educational housing sector.

Broekhuis [16] runs a large multi-annual maintenance plan (MJOP). At the moment, 21 major projects are running of €4 million in total. The total plan consists of 35 major projects, of both new construction, as well as renovation. Additionally, there is a large growth challenge in Utrecht. Her aim is to tackle this with qualitatively good buildings by:

- Providing good IEQ in the buildings.
- Developing sustainable buildings, also for educational purposes.
- Reducing exploitation costs.

Key findings

Sufficient knowledge is present at the major school boards, but this is not the case for smaller school boards. Also municipalities experience a lack of knowledge.

In case of renovation, Broekhuis [16] distinguishes mandatory and extra sustainability measures. For the latter, she focuses on measures that are earned back in 10-15 years, for two reasons: first, because installations generally have a depreciation period of 10-15 years, then renewal is necessary. The depreciation periods should be added to the measure packages. Second, because of technical developments in the market. She wants to apply the state-of-the-art installations. "If you take measures with a longer payback period, you anticipate for an aging building" [16].

Measures with a payback period of less than 5 years are incorporated in the MJOP. For this purpose, PCOU & Willibrord engaged in a 7 year maintenance contract with market parties. In this contract they set up arrangements to get all installations to level three, according to NEN-2767, and made a sustainable maintenance plan for the remaining years. This is in line with the Activiteitenbesluit Milieubeheer [3].

Broekhuis [16] responds positively to the Decision Flowchart. The building periods are recognizable. Furthermore, she thinks that school boards are able to organize renovation projects better with the knowledge this flowchart provides. Additionally, she agrees that this will also have a positive effect on the IEQ in the renovated school buildings.

She does provide some feedback on the flowchart. It misses a question that stipulates who is responsible for the quality of the school buildings. This should be clear, as well as the sustainability ambition for the school building. Then, it becomes easier to determine how much funds should be brought in by the municipality. This way, the flowchart can also facilitate in the talks with the municipality. The question; who is 'bouwheer', becomes less relevant, because the quality is stipulated.

Furthermore, Broekhuis [16] indicates that she always applies the traditional procurement method. She did look into the innovative ways, but did not think they are feasible for them. She additionally states that she questions whether the will be feasible for small school boards, if they are not feasible for PCOU & Willibrord. The traditional method is simple, and therefore better in her opinion.

Cor Honcoop is director at SKOSS, Stichting Katholiek Onderwijs Soest-Soesterberg. His housing portfolio comprises of 6 schools. Three of these are rather new (2000, 2005 & 2006). The other three are over 40 years old. Two of the over 40 year old school buildings have recently been renovated (and expanded), as well the school building from 2000. The remaining 40 year old school building is currently being renovated. He runs this school boards solely, with part-time support of a secretary.

Key findings

Although SKOSS only owns 6 school buildings, they have quite some experience in school building renovation. Main reasons for the activity in renovation are appearance of the buildings, and to keep maintenance at a decent level. In the end, a properly maintained building will cost less than cutting in the maintenance budget.

For the housing portfolio management, SKOSS hires an external housing expert (architect). The external expert advises in the development of the MJOP and renovations. For renovation expertise, the school board is dependent on this external expert.

Honcoop [41] indicates, like others have before him, that in practice the decision-making process often starts with the available budget. The decision to start with the existing situation and sustainability ambitions is made on purpose to not restrict the sustainability ambitions due to limited budgets.

Honcoop [41] states that the opportunity to lease empty building parts is an important way to cope with excess space. This opportunity can also be used to cope with fluctuating student numbers. If the student numbers have dropped in recent years, but are expected to rise again in the future, the temporary excess space can be rented out for other purposes.

Furthermore, the decision flowchart is more a 'think' flowchart, according to Honcoop [41]. As it makes school boards aware about the questions, subjects and opportunities that they need to consider. Also, the importance of student forecasts was mentioned. These are important in the question: 'for how long is the school building being used?'. Student forecasts are generally available at the municipality and taken into account in the development of IHP's, therefore they are not added to the flowchart.

Honcoop [41] confirms that he would definitely use the decision flowchart, if made available. The flowchart presents proper insight in the opportunities in school building renovation. The insights the decision flowchart

presents in the effects of the indoor environmental quality on performance and health, are useful insights that could lead to more attention towards IEQ improvement in renovation of school buildings.

Ard Den Outer is strategic advisor 'opdrachtgeverschap en marktbenadering' at the municipality of Rotterdam. He focuses, among other things, on improving the educational housing stock in Rotterdam. For this purpose, Rotterdam is investing €500 million in renovating and improving the sustainability of 150 school buildings [43]. Additionally, Den Outer [26] is a member of the Dutch Green Building Council [23].

Key findings

Outer [26] agrees with the way the top half is structured and the considerations that it includes. In the technical measure packages, he misses the BENG option. If the flowchart is to be used for a longer period, the BENG option is important, because by 2040/50 BENG will be mandatory for existing buildings. If the lifetime of a building is prolonged by 25 years in the coming years, it will still exist after 2040 and possibly subject to BENG-demands.

The BENG-demands for school buildings are:

- Energy demand of max. 50 kWh/m^2/year
- Primary fossil energy use of max. 60 kWh/m^2/year
- A renewable energy share of min. 50%

These demands are less specific than the Frisse Scholen demands. Therefore, it is more complicated to provide a generic indication of measures, with substantiated assumptions.

The decision to not develop BENG-packages is made for the following reasons:

- The BENG-demands are not comparable with the Frisse Scholen klassen.
- BENG focuses solely on the Planet dimension, which could affect the PPP-balance of renovated school buildings.
- The energy demand and use are very dependent on the way of education. E.g. use of digital screens and computers, or the number of students.

The way this flowchart copes with portfolios is less useful for Den Outer [26]. With a portfolio of 150 schools, it is quite a job to repeat the top part 150 times. This is only possible for medium-, and small-sized school boards.

Table 6.1: Responsibilities in renovation (rule of thumb) [26].

Funding goal	Responsible
Energy efficiency	School
IEQ improvement	Municipality
Lifetime extension	Municipality
Building flexibility	Negotiable

This distinction can be included in the decision flowchart, as it provides a basis for discussion between school boards and municipalities. It can help school boards in making municipal funds available for renovation.

6.4. Design finalization

Following these final design tests, the flowchart is finalized. As Broekhuis [16] indicates; the quick wins should be grouped under maintenance, which are funded by the party who takes the financial risks. Which can be the school, the beheerstichting or a third party (ESCo). This question is added to the flowchart. In case of renovation the funds are delivered by the school board and municipality together. The 'rule of thumb' by Den Outer [26] can be used here, and is therefore added in the Legend. Borrowing is grouped under 'own means', because the loan is paid off with the lump sum subsidy received from the ministry of Education, Culture & Science.

After this, market party selection starts, where the choice can be made between traditional procurement or innovative procurement. The latter guides towards organizational opportunities.

The 'Nul-op-de-meter'-package and the NLII-initiative are removed for the time being, because these instruments are not available yet.

Flowchart design steps by Fryman [35]

With the designs finalized, the decision flowchart development steps by Fryman [35] are completed.

1. Determine the process to be flowcharted

   The process to be flowcharted is the decision-making process for the renovation of school buildings. This is the process presented in Figure 4.6. The flowchart starts off with examining the existing situation, by determining the year of construction. With the building typologies, this simple question presents a lot of information. Then, the desired situation is determined using the desired lifetime of the building and the sustainability ambition. This guides towards (technical) means to reach this desired situation in the form of technical measure packages. The indication of the investment costs of these measures present the costs to reach the desired situation. Finally, the way of financing (and organizing) the project is covered.

2. Determine the level of detail

   The decision flowchart is generic, and therefore at macro level. It presents an indication of the investment costs and how to finance and organize the renovation. But, for actual execution of the project, these outcomes need to be addressed for the specific building(s) that need renovation.

3. Determine the process boundaries

   The flowchart focuses on the renovation of existing Dutch primary school buildings. New construction is disregarded in this flowchart. The opportunities to improve the energy performance and IEQ focus building- and installation alterations. Measures that change e.g. the behaviour of occupants are also disregarded.

4. List the beginning activity

   The year of construction of the school building is determined as the beginning activity. School boards are generally able to answer this question. Also, this presents an immediate distribution for the technical measures. Starting with e.g. the ambition for the school building also presents an immediate distribution, but this could be a tricky question to answer and 'scare away' users. If users are lured into the flowchart with a simple initial question, it is expected that they are more willing to finish it.

5. List the sequential activities

   The sequential activities, or in this case considerations are;

   - Desired use period of the school building
   - Ambition level for the school building
   - Means to reach the desired ambition level
   - Cost indication
   - Financial responsibilities
   - Way of funding
   - Way of financing
   - Form of organization

6. List the ending activity

   The key take-aways for school boards are insight in

   - The technical, financing and organizational opportunities.
   - The effects of measures on IEQ en of IEQ on occupant performance and health.
   - The decision-making process, and the consideration that need to made.

7

Conclusions

Due to a complex, and tight financial situation, school boards are having difficulty improving the sustainability of their school buildings. This complicates the effort to renew this, currently very old, Dutch educational housing stock, and fails to improve the, currently poor, building performance in terms of energy and indoor environmental quality. An underlying issue is expected to be the lack of renovation knowledge and experience by school boards. By improving the knowledge of school boards, the expectation is that they are enabled to better organize and finance renovation projects and consequently have increased financial room for IEQ improvements. This results in an improved People, Planet, Profit balance. Given these issues and expectations, the following research question is formulated.

How can school boards take well-founded decisions about renovation of school buildings resulting in an improved People, Planet, and Profit balance?

Extensive desk research, supplemented by an interview with a housing expert, presents a solid overview of the Dutch educational housing sector. It presents barriers for renovation towards sustainable school buildings and available, stimulating opportunities and initiatives. Following expert meetings, a decision-support framework was developed. Which was tested and evaluated in interviews with educational housing experts from school boards and in a focus group with financial experts, resulting in several iterations of the framework. Throughout this thesis, the following sub research questions are answered. A short conclusion on each sub question is presented here.

1. What does sustainability mean for school buildings?
Elkington's [32] definition of sustainability provides guidance in tackling the main issues concerning indoor environmental quality (People), energy efficiency (Planet) & investment costs (Profit). Good balance between these three dimensions in the renovation of school buildings, will result in sustainable school buildings.

2. What is the current state of the Dutch primary school building stock?
The Dutch primary educational building stock is characterized by old buildings, performing poorly in terms of energy efficiency and IEQ. Primary school buildings rarely comply with existing laws and decrees, partly facilitated by lack of supervision. The educational housing stock can be divided in three building periods, based on building typologies: <1975, 1975-1992 & >1992.

3. What is the legal framework for school building renovation?
Several laws and decrees state something about the educational housing sector. The bouwbesluit [4] and Activiteitenregeling Milieubeheer [3] are most relevant as they directly stipulate building requirements. These should be considered in the development of technical measure packages.

4. How are decisions by school boards on sustainability measures currently taken?
The current decision-making process forms the basis for the development of the decision flowchart. Key stakeholders in the decision-making process are: school boards, municipalities, housing experts, contractors, ESCo's and financiers. The opportunities should present ways that increase the interests of the latter three stakeholders.

5. What are the barriers in the development of sustainable primary school buildings?
Technical measures can have adverse effects, when not both energy efficiency and IEQ are taken into account. Split incentives, unclear responsibilities and conflicts of interests are issues that result from the organizational structure. Furthermore, difficulties in financing renovation and lack of knowledge in financing and renovation opportunities form barriers for renovation. These barriers should be considered in the development of the decision flowchart and technical measure packages.

6. What are the opportunities in school building renovation?
Government agencies, independent knowledge institutions and market parties develop initiatives that help finance and organize school building renovation, but due to fragmentation of supply school boards cannot see the wood for the trees. Structure and insight in opportunities should support school boards in renovation projects.

7. What generic combination of technical measures can improve the sustainability of school buildings in renovation?
Technical measure packages are presented that consider both energy efficiency and indoor environmental quality improvements. Furthermore, the packages present insight in the effects on energy efficiency and IEQ, investment costs, and payback period.

8. How can technical, financial and organizational opportunities be evaluated by school boards?
A decision flowchart presents considerations that need to be made in the renovation decision-making process. By walking through these considerations, school boards are guided towards technical, financial and organizational opportunities.

9. To what extent does insight in renovation opportunities result in improved People, Planet & Profit balance in school building renovation?
In interviews, school boards express that the decision flowchart presents a basic level of knowledge and insight in school building renovation. This knowledge and insight can help them in organizing renovation projects, resulting in more awareness and financial room to invest in IEQ improvements. This can result in a better PPP balance.

Answering the main research question:

How can school boards take well-founded decisions about renovation of school buildings resulting in an improved People, Planet, and Profit balance?

The decision-making process in school building renovation is a very dynamic and cluttered process. In general, many discussions with the municipality precede any decision regarding renovation. Key issue in most of these discussions is financing: what measures are necessary to take? What is the necessary budget? And who is going to fund which part of the renovation? For this reason, the respondents often indicated that the flowchart should begin with the 'financing part'. Yet, beginning with the 'finance part' can limit their sustainability ambition, because school boards generally prefer funding with their reserves, limiting the budget. If they first state their ambitions, these are less restricted by budget. Then presenting ways to meet their ambitions can commit them to these ambitions, making them more willing to change their view regarding external financing. The respondents could find themselves in this explanation. For the rest, the respondents agreed with the general structure of the flowchart.

The respondents were positive about the way the flowchart presents an overview of the opportunities. Even though, some were sceptic about some of the more innovative organizational forms, it does inform them of the opportunities that are at hand, and their benefits. Although most respondents are aware of the available opportunities, because they are experts in the educational housing market, they indicate that in general the level of knowledge about renovation opportunities is insufficient. Thus the insight in renovation opportunities is very useful for the average school board, who does not have the capacity to hire a housing expert. The respondents expect that the flowchart helps ease the organization and financing of renovation projects.

The attention the flowchart presents on the effects of indoor environmental quality on the quality of education, is regarded as a valuable addition to the flowchart. It evokes necessary problem awareness, which is

currently an underestimated aspect in school building renovation. Respondents expect that the focus on indoor environmental quality can increase the attention to the indoor environment in the renovation of school buildings.

The increase in problem awareness and attention to indoor environmental quality, could lead to more balanced renovations in terms of People, Planet & Profit, as the importance of the People dimension is emphasized and recognized. The Planet dimension, or energy performance, will remain important due to (inter)national pressure to improve energy efficiency. Also the Profit dimension will remain important given the complicated financing structure. Whether the decision flowchart can increase the financial room available for indoor environmental quality improvement is dependent on the willingness of school boards to abandon their current views on funding and financing and to engage in more innovative ways of organization and financing. Additionally, the market should find ways to speed up the development and learning curve of these innovative opportunities, making them more trustworthy.

Limitations & recommendations

Being a graduation thesis, the research was subject to limited time and resources, causing several limitations. For these limitations, recommendations are provided that can be followed in future work. These limitations and recommendations are divided in managerial, scientific and societal limitations and recommendations.

Managerial recommendations

The decision flowchart ends with the selection of market parties. After this, a procurement and contracting issue remains. Providing insight and guidance on this issue, would contribute to the comprehensiveness of the flowchart. For future research, it is advised to consult with procurement and contracting experts, with experience in the educational housing sector. With their insight, further guidance in these issues can be provided. Such guidance can be very useful in further talks with market parties. In the development of this addition, it is important to present ways to capture guarantees on contractors.

The contribution of experts (including the interviewed school boards) was of great value for this research. As key players in the Dutch educational housing sector, they have the expertise to judge the issues and needs of school boards. Nevertheless, the flowchart should be tested among small school boards as well. Only one small school board (6 school buildings) was interviewed to test the design. Although this small school board was positive, the validity of this test is questionable. More tests among smaller school boards and 'eenpitters' could increase validity. Especially, because 'eenpitters' are repeatedly mentioned as key beneficiary to the flowchart. 'Eenpitters' represent almost half of the Dutch primary school boards, but they only own 8% of Dutch school buildings. In a focus group, their ideas could be gathered, supporting the generic character of this flowchart. Testing among participation councils of schools could also present expectations about the added value of the flowchart to these stakeholders.

As expressed above, it is preferred to test the designs in a focus group, compared to separate interviews. In an interview, only one perspective is present, while in a focus group the perspectives of multiple school boards would be discussed. A focus group can contribute to the generic character of the designs, as solutions can be sought that apply in the case for all attendees.

The technical packages that follow from this research are a proper first indication of technical opportunities. But, if the flowchart is to be used for many years to come, more ambitious sustainable solutions should be presented. Extending the building lifetime for over 25 years, should consider future building requirements such as BENG and NOM (Nul-op-de-Meter)-buildings. The development of such technical packages can be the focus of future research.

Prior to this research, engineering and consultancy agency Arcadis, expressed the desire to bring together the perceptions of school boards, municipalities, financiers and contractors. Although partly treated, this issue did not receive as much attention as Arcadis may have wanted, as it somewhat deviates from this research' main question. A way to tackle this challenge is to develop a 'serious game', where school boards, municipalities, financiers and contractors can play a game that simulates the preparation for renovation of a school building. This could enable them to familiarize with the perceptions of others.

In the end, a digital version of the flowchart could be developed. This makes it possible to provide links with existing instruments, and enables easy use and sharing of the tool. Furthermore, additional information can be provided. Example given, the technical packages can be presented in full, in an instant. Further explanation can be provided about the organizational forms, indicating the benefits of e.g. upscaling or unburdening of housing management. Also, example calculations can be provided, which indicate the benefits

financing with loans in comparison with funding from reserves. Currently, school boards remain reserved towards such opportunities, such information can change this.

For further development of the decision flowchart, the following rules should be kept in mind:

1. The strength of the flowchart is its simplicity.
2. Don't develop something new, but bring together existing instruments.
3. Use the language of the educational sector.

Scientific recommendations

The interviewees recognized the added value of the decision flowchart. Also, the attention to indoor environmental quality is appreciated and supported. The outcomes of this research are limited to qualitative expectations, and present a first indication of the added value renovation knowledge can have in improving the balance between People, Planet & Profit. To further substantiate these expectations, quantitative effects can be researched using e.g. case studies. In these case studies, school boards who have recently performed a renovation, can apply the flowchart these renovated school buildings. The effects of the technical measure packages that result from the flowchart can be determined mathematically using thermal energy balance calculations, and can be compared with the executed renovation. Also, the financing outcomes can be compared with the executed renovation. By determining the Total Cost of Ownership, the financial situations can be compared.

Apart from the effects of indoor environmental quality on health, productivity and performance, little scientific research is conducted regarding school building renovation. Especially the relationship between knowledge by school boards and the consideration of the People, Planet & Profit dimensions has not been researched to date. In this area, this research is the first in its form and can be built upon to further improve the Dutch primary educational housing stock.

This scientific research, with a practice-oriented character, presents an elaborate overview of the existing situation in the Dutch educational housing sector and identifies several issues. By presenting the decision-making process in combination with renovation opportunities, the decision flowchart aims to support the renovation decision-making process by providing knowledge.

Societal recommendations

To further improve the Dutch primary school building stock, this research contributes to a better work & learning environment for staff and students. With better indoor environmental quality, their performance, productivity and health improves. Additionally, this can have direct and indirect monetary effects. Directly through e.g. sick leave, or indirectly through higher income in the adult life of students.

But, a lack of problem awareness is apparent. Not only at school boards, but also student and their parents. Improving the awareness of the effects that school buildings have on performance, productivity and health, could lead to more attention to IEQ improvement. Through the participation council, parents can influence school boards in the development of school buildings with proper indoor environmental quality. As this decision-support framework mainly focuses on school boards, parents are less involved. Awareness of parents can be awakened through general media or education oriented organizations such as Ruimte-OK or PO Raad.

A

Existing sustainable measure packages and lists

Verduurzamingsmaatregel		Invloed op					Terugverdientijd (indicatie)						Nummer erkende maatregel WMB	Zelf invullen		
			Binnenmilieu				Natuurlijk moment			Zelfstandig moment						
NL-SfB code	Omschrijving	Energiegebruik	Lucht	Temperatuur	Geluid	Licht	≤ 5 jaar	5 -10 jaar	> 10 jaar	≤ 5 jaar	5 -10 jaar	> 10 jaar		N.v.t.	Gerealiseerd	Verbeteroptie
55 - Koelinstallaties																
55.001	topkoeling in plaats van airconditioning (volledige koeling) toepassen	+		+			●			●						
55.002	adiabatische ruimtekoelsystemen toepassen	+		+			●			●						
55.003	vertraagd inschakelen van compressoren	+			+		●			●						
55.004	toerenregeling op de koelmachine aanbrengen	+			+		●			●						
55.005	goede luchtstroming langs de condensor	+			+		●			●						
55.006	leidingisioatieaanbrengen (incl appendages isoleren)	+					●				●					
55.007	vrije koeling toepassen	+			+						●					
55.008	periodiek onderhoud koelmachine: o.a. schoonmaken koellichamen, condensors	+					●			●						
56 - Warmtedistributie-installaties																
56.001	pompschakeling aanbrengen (warmteopwekking)	+					●			●						
56.002	toerenregeling aanbrengen op de cv-pomp (warmteopwekking)	+					●			●						
56.003	warmteafgifte van de radiatoren verbeteren	+		+			●			●						
56.004	verwarmingsinstallatie in meerdere groepen splitsen	+		+						●						
56.005	downflow ventilatoren toepassen voor een gelijkmatiger warmteverdeling	+		+			●				●					
56.006	isolatie aanbrengen om leidingen en appendages															
	· *indien aardgasverbruik < 170.000 m3 per jaar*	+					■			■			7			
	· *anders*	+					●				●					
57 - Luchtbehandelingsinstallaties																
57.001	warmteterugwinning uit ventilatielucht toepassen															
	· *indien CR of VR CV-ketel aanwezig*	+	+	+			■			■			4			
	· *anders*	+	+	+			■				●		4			
57.002	ventilatiesysteem indelen naar gebruikszones met eigen gebruikstijden	+	+								●					
57.003	uitwendige kanaalisolatie aanbrengen	+		+			●				●					
57.004	luchtweerstand verlagen door het vergroten van het filteroppervlak	+	+								●					
57.005	ventilatiestroom verbeteren (via luchttoevoer gevel of verkeersruimte)	(-)	+								●					
57.006	voorzieningen bij luchttoevoer om tocht tegen te gaan	+	+	+			●				●					
57.007	filters reinigen en/of vervangen		+													

Figure A.1: Sustainable measures matrix, not in full [102]

Acknowledges measures Activiteitenbesluit Milieubeheer	Energy	Indoor Environmental Quality			
		Air quality	Temperature	Lighting	Noise
Cavity wall insulation	+		+		+
Time switch ventilation	+	+			
Cascade control ventilation	+	+			
Twin coil system ventilation (heat recovery)	+	+	+		
Weather-dependent regulation supply CV installation	+				
Weather-dependent control startup times CV installation	+				
Insulation of hot water pipes	+	+			
HR107 boiler (heating)	+	+	+		
Veegpulsschakeling	+				
TL5 lighting	+			+	
LED lighting inside	+			+	
Motion and light sensitive switch lighting	+				
LED lighting outside	+				
LED advertising lights	+				
Gas-fired HR boiler (tapwater)	+				

Figure A.2: Effects on Acknowledged measures from the Activiteitenregeling Milieubeheer [3]

ECN	From energy label ... to energy label C				Energy	Indoor Environmental Quality			
	G	F	E	D		Air quality	Temperature	Lighting	Noise
Façade insulation	x				+		+		+
Roof insulation	x				+		+		
HR++ glazing		x	x		+		+		+
HR107 boiler	x			x	+		+		
Lighting (LED)	x	x	x		+			+	
Sweeping switch lighting	x	x	x		+				
Motion and light sensitive switch lighting	x	x			+				
PV panels		x			+				
Investment €/m2	142-212	87	51	16					
Savings €/m2	13,00	7,00	6,00	2,00					
Payback Period	11-17y	12y	9y	8y					

Figure A.3: Effects on energy saving measures by ECN [60]

Arcadis	From building period ... to energy label C						Energy	Indoor Environmental Quality			
	<1965	1966-1979	1980-1988	1989-1994	1995-2002	2002-2007		Air quality	Temperature	Lighting	Noise
Floor insulation	x	x					+		+		+
Façade insulation	x						+		+		+
Roof insulation	x	x	x				+		+		+
HR++ glazing	x	x	x	x	x		+		+		+
HR107 boiler	x	x	x	x			+		+		
Lighting	x	x	x	x	x		+			+	
Bal. Vent. + heat rec.				x			(+/-)	+	+		
Heat pump							+		+		
Investment €/m2	113	86	79	84	49						
Savings €/m2/year	13,44	9,91	9,75	9,28	2,93						
Payback Period	20-25jr	20-25jr	20-25jr	10-15jr	10-15jr						

Figure A.4: Effects on sustainable packages for label C by Arcadis [10]

Arcadis	From building period ... to energy label B						Energy	Indoor Environmental Quality			
	<1965	1966-1979	1980-1988	1989-1994	1995-2002	2002-2007		Ai quality	Temperature	Lighting	Noise
Floor insulation		x					+		+		+
Façade insulation		x					+		+		+
Roof insulation		x	x				+		+		+
HR++ glazing		x	x	x	x		+		+		+
HR107 boiler		x	x	x			+		+		
Lighting		x	x	x	x		+			+	
Bal. Vent. + heat rec.			x	x	x		(+/-)	+	+		
Heat pump						x	+		+		
Investment €/m2		113	135	84	78	110					
Savings €/m2/year		13,44	14,25	9,28	3,90						
Payback Period		20-25jr	20-25jr	10-15jr	10-15jr	5-10jr					

Figure A.5: Effects on sustainable packages for label B by Arcadis [10]

Arcadis	From building period ... to energy label A						Energy	Indoor Environmental Qualiy			
	<1965	1966-1979	1980-1988	1989-1994	1995-2002	2002-2007		Air quality	Temperature	Lighting	Noise
Floor insulation		x					+		+		+
Façade insulation		x					+		+		+
Roof insulation		x					+		+		+
HR++ glazing		x		x	x		+		+		+
HR107 boiler		x		x			+		+		
Lighting		x		x	x		+			+	
Bal. Vent. + heat rec.				x	x		(+/-)	+	+		
Heat pump						x	+		+		
Investment €/m2		113		84	78	110					
Savings €/m2/year		13,44		9,28	3,90						
Payback Period		20-25jr		10-15jr	10-15jr	5-10jr					

Figure A.6: Effects on sustainable packages for label A by Arcadis [10]

B

Renovation cycle

During desk research, the renovation cycle in Figure 12 was found. This represents a renovation cycle for sustainable regional development. With minor alterations, a new cycle is developed, presented in Figure 13. In a semi-structured interview, this altered renovation cycle is discussed with housing and facility employee, Frank Rubel [76]. Rubel emphasized the importance of the information collection and analysis phase. In this phase, school boards and municipalities develop MOP's, IHPs, and PoR's. These new insights are added to the renovation cycle, resulting in the service life planning process presented in Figure 4.7.

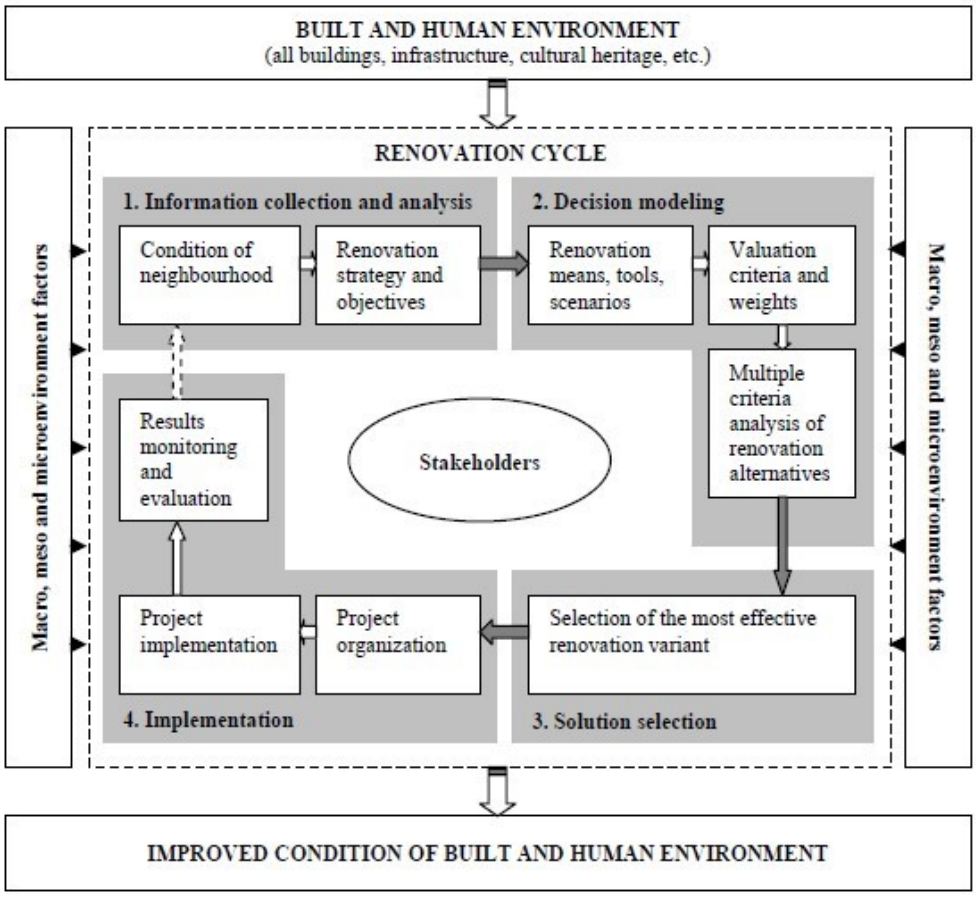

Figure B.1: Cyclic renovation process [89]

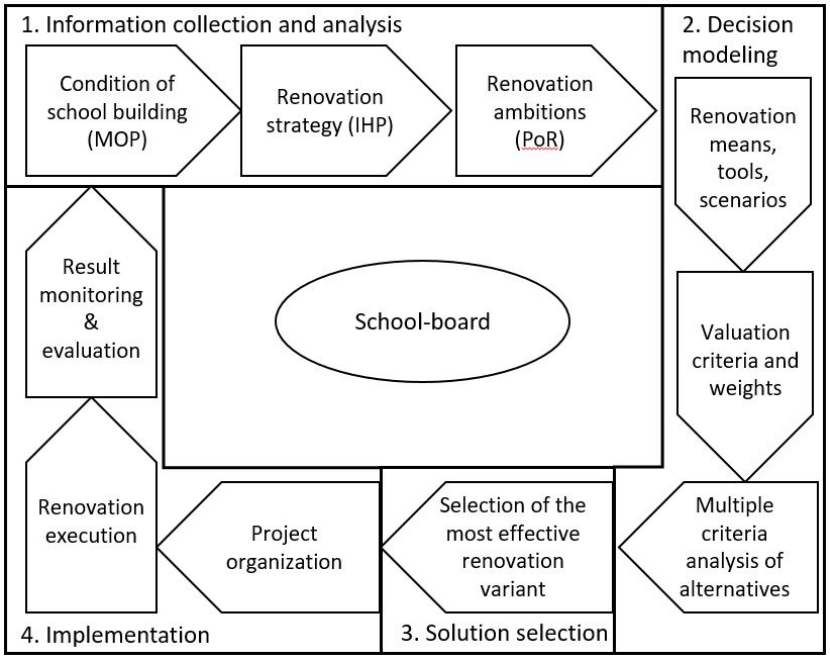

Figure B.2: Altered renovation cycle

C

Expert meetings

Expert meeting 1

April 12th, 2017, Attendees:

1. A knowledge manager specialized in the improvement of educational housing, Ruimte-OK.
2. Managing director, BAM Techniek Energy Systems.
3. A contracting and procurement expert from a Dutch law firm, Boot advocates.
4. Sector leader education, Arcadis.
5. Senior project leader, Arcadis.

Meeting organization

This first meeting is a brainstorm session, where attendees are encouraged to bring in as much information as possible. Three main subjects need to be addressed: Goal, target audience & relevant subjects.

Key findings

- The goal of the decision flowchart:
  - The main goal of the flowchart was defined as: to systematically guide users through knowledge and insights in renovation opportunities to provide handles to start a renovation project.
- The target audience:
  - The different layers of the schools' organization should be able to use the flowchart: school boards, housing specialists and school management.
- The subjects to cover:
  - The main subjects that should be covered in the decision flowchart are the project organization, finance, technical measures and legal guidelines/boundaries.

Furthermore, the following wishes have been formulated:

- The flowchart should refer to locations where detailed information is available
- There should be thought of how the flowchart can be brought into the market (e.g. workshops)

The goal for the following meeting is to compose documentation that can be useful for the development of the decision flowchart.

Expert meeting 2

May 16th, 2017, Attendees:

1. A senior advisor on utility buildings specialized in education, RVO
2. A knowledge manager specialized in the improvement of educational housing, Ruimte-OK.
3. Managing director, BAM Techniek Energy Systems.
4. Sector leader education, Arcadis.
5. Senior project leader, Arcadis.

Meeting organization

This meeting required more structure than the previous to steer towards actual decisions. Therefore, a list of themes (and relevant documents) is drafted in advance, to consider these in the meeting. This steered the discussion towards the structure of the flowchart.

Key findings

During the second expert meeting, some conclusions from the previous meeting were briefly discussed. The target audience stayed the same as in the first meeting. The goal of the flowchart was extended with creating awareness about what considerations need to be made to come to opportunities for school building renovation.

Furthermore, during this expert meeting the following issues were discussed:

- Example projects were discussed. It would be an idea to see if lessons can be learned from other projects. Other projects might also function as an example why a decision-flowchart is necessary.
- Is the flowchart providing decision support for building portfolio's or single buildings?
- How can technical measure packages be defined? They can be distinguished in terms of sustainability ambition. E.g. packages that are payed back within 5 years (according to Activiteitenbesluit Milieubeheer), nearly energy neutral building (BENG, bijna energie neutral gebouwen) and energy neutral buildings (ENG, energie neutral gebouwen). Also, dependent on the desired exploitation period/lifetime extension of the building.
- How can building adjustments/expansions be considered?
- Make sure to emphasize that the recommendations are generic, and that school boards need to hire a consultant/architect to develop a detailed plan. These opportunities only provide an overview of possible solution.

The goal for the following meeting is to compose a first draft of the flowchart, given these key findings. This functions as a basis for discussion in the following meeting. If possible, this draft should be discussed with a school board.

Expert meeting 3

June 20th, 2017, Attendees:

1. A senior advisor on utility buildings specialized in education, RVO
2. A knowledge manager specialized in the improvement of educational housing, Ruimte-OK.
3. Managing director, BAM Techniek Energy Systems.
4. A contracting and procurement expert from a Dutch law firm, Boot advocates.
5. Sector leader education, Arcadis.
6. Senior project leader, Arcadis.

Meeting organization

By delivering a draft setup of the flowchart, the discussion is about aspects that should be added, removed or changed. The discussion follows the structure of the flowchart. During this meeting the first version of the flowchart is used (Figure E.1).

Key findings

Mainly the top part of the flowchart is discussed. The sequence of questions is better structured:

- Year of construction
- Exploitation horizon
- Sustainability ambition
- Technical measures

The formulation of concepts like 'horizon' and 'ambition' are discussed extensively. The previous formulation, life extension of the building, did not cover the right meaning.

Furthermore, the financial opportunities should be organized differently. The main financing categories are:

- Own means
- Borrowing
- Energy Service Companies
- Innovative financing opportunities

The innovative opportunities should receive less attention than the others. As it is advised to provide mainly proven, repeatable solutions.

Following the findings in these meetings, the second version of the decision flowchart was developed (Figure E.2)

D

Interview questions

Informative interview

Interviewee

- Frank Rubel, housing specialist at Swalm & Roer and member of the PO-Raad.

Interview questions

Algemeen

- Kunt u iets over uw achtergrond vertellen?
- Wat zijn uw taken bij Swalm & Roer?
- Kunt u iets vertellen over vernieuwbouwprojecten bij Swalm & Roer?
  - voorbeeldprojecten?

Aanloop naar vernieuwbouw

- Is er een directe aanleiding tot vernieuwbouw? Zo ja, wat?
  - Verouderd gebouw, energiebesparing (kosten), vervanging onderdeel leidt tot grootse vernieuwbouw, groei/krimp.

Besluitvormingsproces

- Welke partijen zijn betrokken in het besluitvormingsproces?
  - Schoolbestuur, huisvestingsspecialist, schoolleiding, ouders, leerlingen, gemeente, aannemers, financiers, ..?
- Welke beslissingen worden gemaakt?
- Wie neemt welke beslissingen?
  - Verantwoordelijkheden
- Op basis van welke worden beslissingen genomen?
- Wanneer in het besluitvormingsproces?
  - Volgorde van beslissingen
- Welke afwegingen worden gemaakt?
  - Prioriteit energie, binnenmilieu of kosten?
- Verwacht u dat dit anders is bij kleinere schoolbesturen?
  - Zo ja, in welk opzicht?

Vernieuwbouwproces

- Hoe ziet het vernieuwbouwproces eruit? Voorbeeld:

  1. Integraal huisvestingsplan: opstellen visie en doelen
  2. Voorontwerp: opstellen budgetten
  3. Plan van eisen: opstellen criteria
  4. Aanbesteding: kiezen aannemers
  5. Detailontwerp: concretiseren duurzaamheidsmaatregelen
  6. Uitvoering
  7. Beheer

Of:

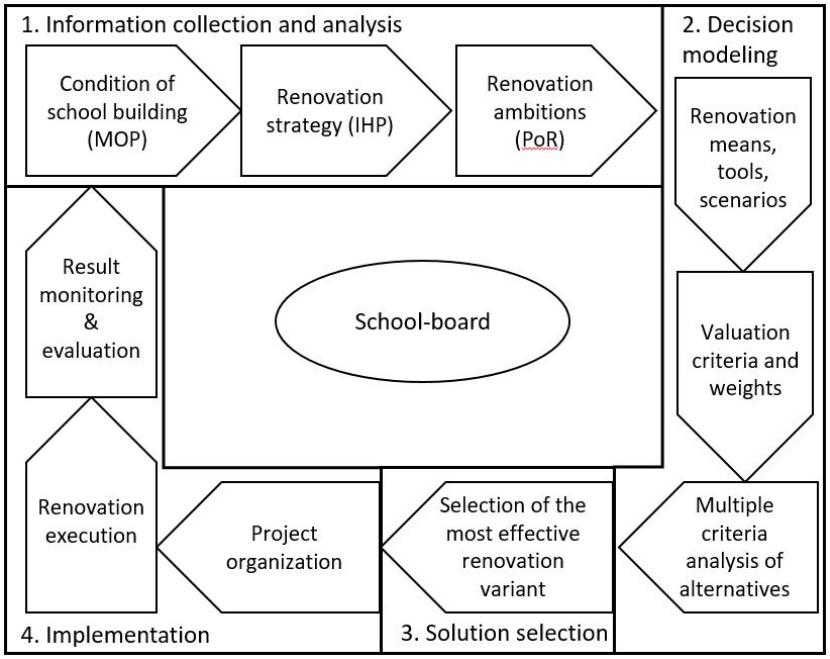

Figure D.1: Altered renovation cycle

Barrieres bij vernieuwbouw

- Ervaart u barrieres in het vernieuwbouw (besluitvormings)proces?
  - Zo ja, welke?
- In hoeverre kunnen deze barrieres, volgens u, worden aangepakt?

Evaluative interview

Introductie

Mijn naam is Kevin Frankena, Master student Systems Engineering, Policy Analysis & Management (SEPAM) aan de Technische Universiteit Delft. SEPAM is een vervolg op de Bachelor Technische Bestuurskunde. Dit afstudeeronderzoek wordt uitgevoerd voor het behalen van de titel Master of Science. Het onderzoek wordt extern uitgevoerd bij Arcadis en begeleid door Eke Schins. De ontwikkeling van de beslisboom is in opdracht van het RVO en in samenwerking met onder andere Ruimte-OK.

Toelichting onderzoek

De bestaande voorraad Nederlandse PO-gebouwen stamt gemiddeld uit 1976. In het huidig bouwtempo, zal de gemiddelde leeftijd van schoolgebouwen zelfs verder toenemen. Gepaard met groeiende aandacht voor energie efficientie verbeteringen ontstaat noodzaak voor een enorme vernieuwingsslag.

Waar momenteel een derde van de scholenbouwontwikkeling bestaat uit renovaties, wordt een toename verwacht naar de helft. Deze groeiende vraag naar renovatie kan worden verklaard door terugname in de vraag. Hierdoor zal nieuwbouw vaak gepaard gaan met afname in vierkante meters, waardoor scholen eerder geneigd zijn te renoveren.

De druk op de financiën van scholen groeit door aanhoudende besparingen op onderwijs. Het binnenklimaat is één van de eerste aspecten die leidt onder besparingen, bijvoorbeeld door gebruik van goedkope materialen of te grote focus op energiebesparingen.

Financiering is de grootste belemmering in deze vernieuwingsslag. Schoolbesturen hebben zelf doorgaans weinig kennis en ervaring op dit gebied. De markt bezit veel kennis betreffende technische, financierings- en organisatorische mogelijkheden, maar deze kennis is erg versnipperd. Hierdoor zien schoolbesturen door de bomen het bos niet meer.

Dit onderzoek richt zich op het voorzien en bundelen van kennis en mogelijkheden over duurzame renovatie van schoolgebouwen. De verwachting is dat schoolbesturen inzicht bieden in duurzaame oplossingsmogelijkheden in renovatieprojecten, leidt tot beter georganiseerde en gefinancieerde renovaties. Vervolgens moet dit leiden tot meer aandacht voor de kwaliteit van het binnenklimaat.

Interviewees

- Jan Aalberts, Spaarnesant
- Robbert Jan Piet, Ronduit
- Chantal Broekhuis, PCOU & Willibrord
- Ard den Outer, Gemeente Rotterdam (For Ard Den Outer, the background questions about the school board are omitted)

Interview questions

Achtergrondvragen

- Kunt u iets over uw achtergrond vertellen?
- Hoe ziet de bestuursorganisatie bij Spaarnesant eruit?
- Wat is uw rol bij Spaarnesant?
- Wat is de omvang van de portefeuille bij Spaarnesant?
- Wat is uw ervaring m.b.t. renovatie van scholen en de financiering hiervan?
- Wat is de aanleiding voor renovatie?
- Hoe zou u uw kennisniveau beoordelen m.b.t. renovatie en financiering?

Besluitvorming

- Hoe verloopt de besluitvorming m.b.t. renovatie en financiering?
- Welke partijen zijn hierbij betrokken?
- Welke rol speelt het binnenklimaat in de besluitvorming?
  - Oorzaak, bijzaak of doel
- Waar is behoefte aan bij de besluitvorming van renovatie en financiering?

Beslisboom

- Wanneer zou de beslisboom bruikbaar/nuttig zijn in het besluitvormingsproces?
- Welke (nieuwe) inzichten biedt de beslisboom?
  - Financieringsmogelijkheden?
  - Organisatorische mogelijkheden?
  - Technische mogelijkheden?
- Is de structuur van de beslisboom in overeenstemming met de manier waarop keuzes in de praktijk worden gemaakt? Zo nee, hoe zou dit anders kunnen?
- Waar kan de beslisboom, in uw ogen, toe leiden?
- Voor wie kan de beslisboom uitkomst bieden?
  - Verschillende lagen in een schoolbestuur?
  - Gemeente?
- Ziet u punten die verbetering vragen?

Binnenklimaat

- Biedt de beslisboom een bijdrage in de besluitvorming rondom het binnenklimaat? Bijvoorbeeld door:
  - Nieuwe inzichten
  - Structuur in de keuzes
  - Zicht op financiële mogelijkheden
- Is de wijze waarop binnenklimaat in de beslisboom aandacht krijgt een toevoeging?
- Kan de beslisboom leiden tot beter gefinancieerde en/of georganiseerde projecten?
  - En kan dit indirect leiden tot een beter binnenmilieu?

Focus Group

The focus group focuses on the workability and comprehensiveness of the decision flowchart. Therefore, background questions and qualitative expectations as the interviews contain are omitted.

Focus group questions

- Wat is uw eerste indruk van de beslisboom?
- Kunt u zich vinden in de structuur van de beslisboom?
- Biedt de beslisboom inzichten in de financieringsmogelijkheden voor renovatie van basisscholen?
- Missen er financieringsmogelijkheden?
- Zijn schoolbesturen in staat de keuzes in de beslisboom te maken?
- Zo nee, hoe kan dit anders of wat is hiervoor nodig?

E

Decision Flowchart designs

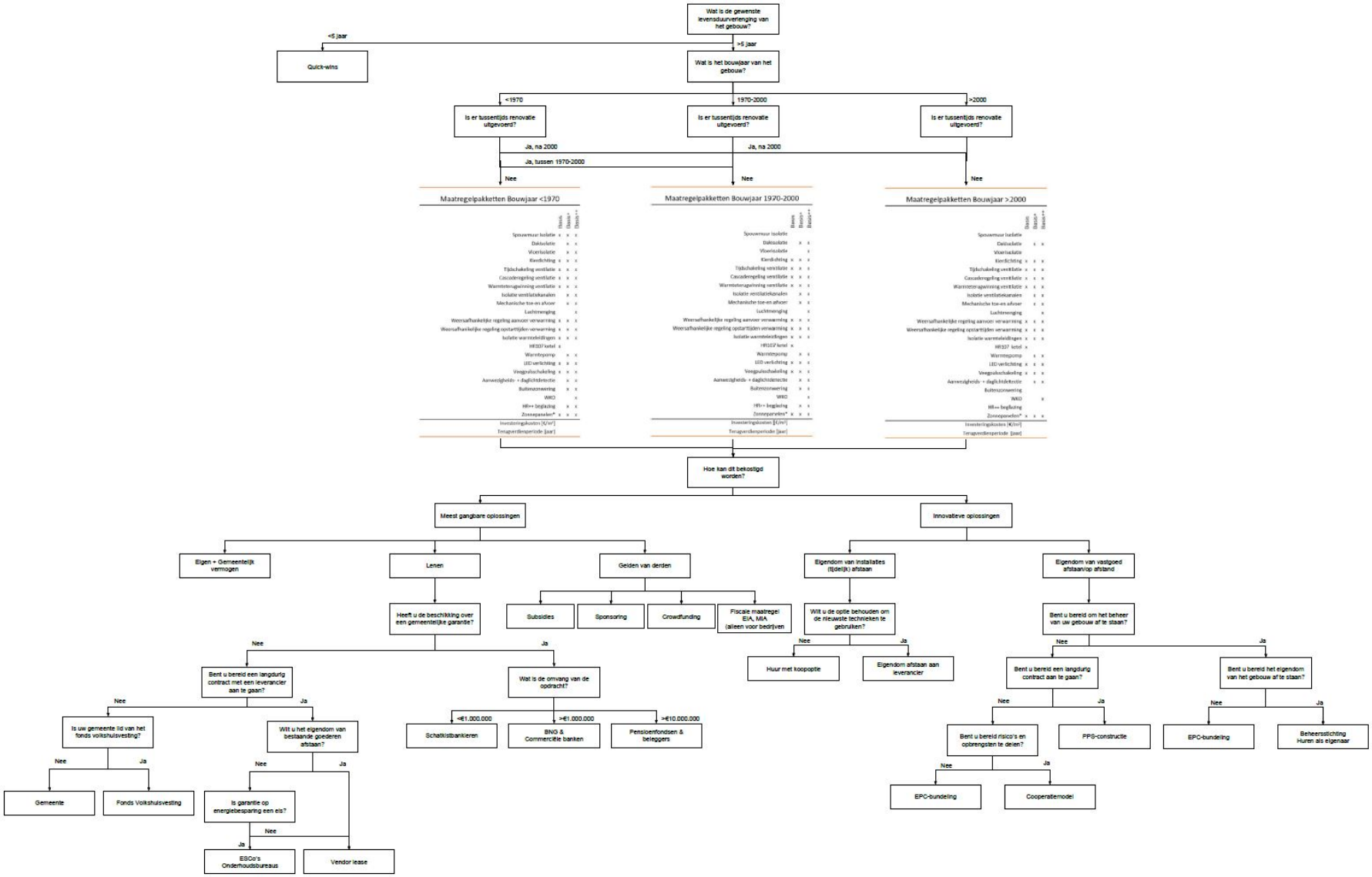

Figure E.1: Decision flowchart, version 1

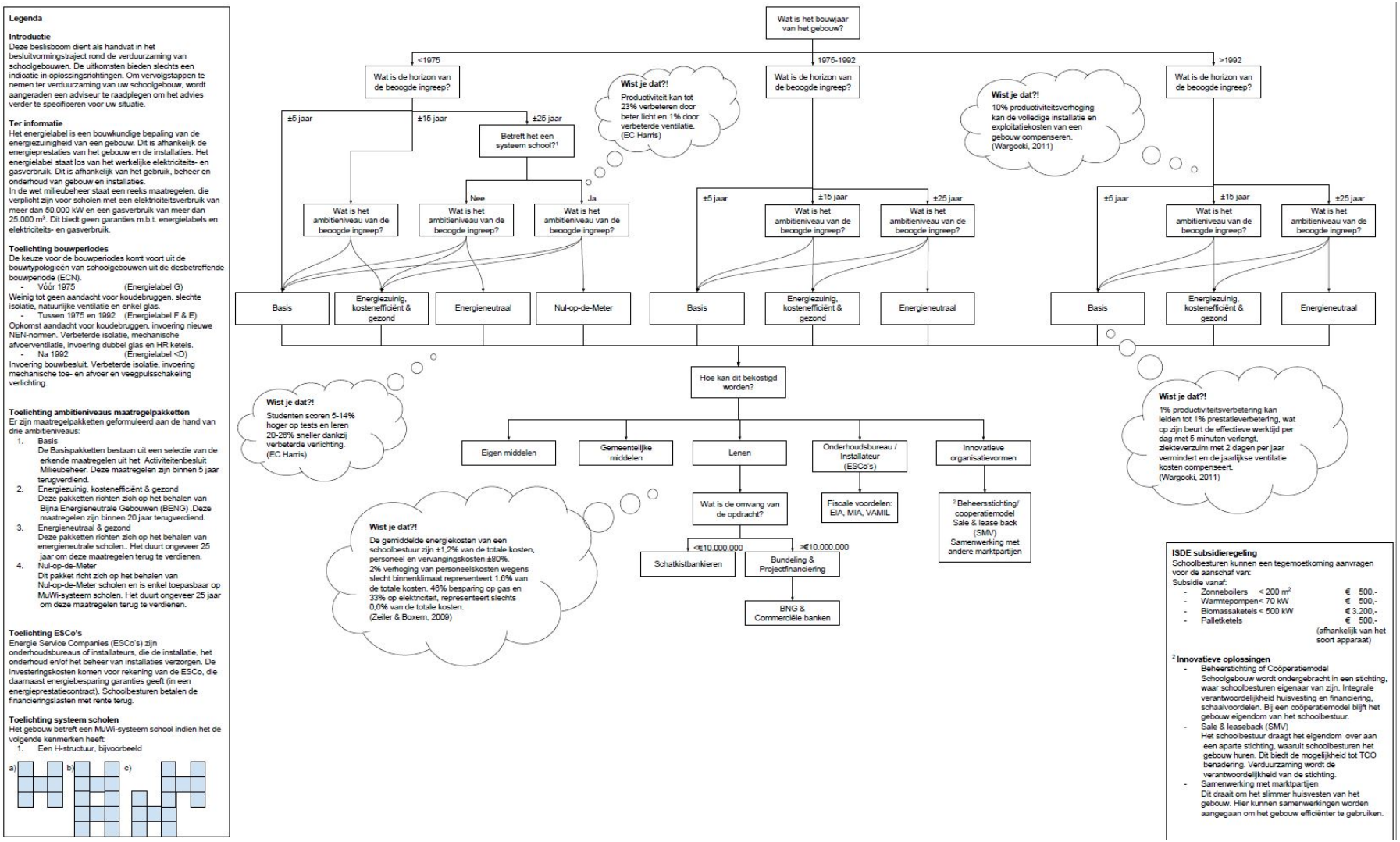

Figure E.2: Decision flowchart, version 2

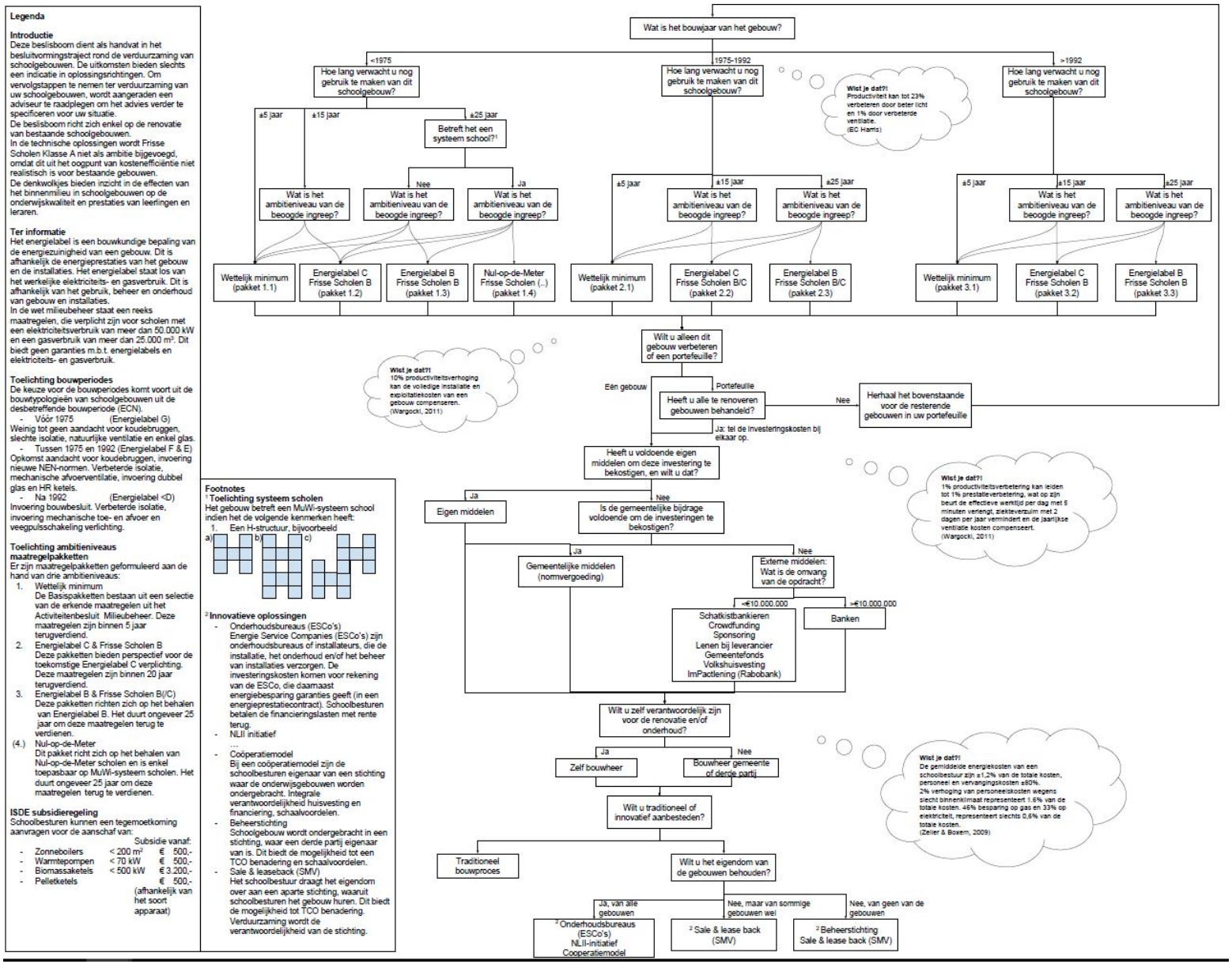

Figure E.3: Decision flowchart, version 3

Duurzame Beslisboom

Voor de renovatie van bestaande schoolgebouwen

Toelichting
Deze beslisboom dient als handvat in het besluitvormingstraject rond de verduurzaming van schoolgebouwen. De uitkomsten bieden slechts een indicatie in oplossingsrichtingen. Om vervolgstappen te nemen ter verduurzaming van uw schoolgebouwen, wordt aangeraden een adviseur te raadplegen om het advies verder te specificeren voor uw situatie.
De beslisboom richt zich enkel op de renovatie van bestaande schoolgebouwen.
In de technische oplossingen wordt Frisse Scholen Klasse A niet als ambitie bijgevoegd, omdat dit uit het oogpunt van kostenefficiëntie niet realistisch is voor bestaande schoolgebouwen.
De denkwolkjes bieden inzicht in de effecten van het binnenmilieu in schoolgebouwen op de onderwijskwaliteit en prestaties van leerlingen en leraren.
In de wet milieubeheer staat een reeks maatregelen, die verplicht zijn voor scholen met een elektriciteitsverbruik van meer dan 50.000 kW en een gasverbruik van meer dan 25.000 m^3. Dit biedt geen garanties m.b.t. energielabels en elektriciteits- en gasverbruik.

Toelichting bouwperiodes
De keuze voor de bouwperiodes komt voort uit de bouwtypologieën van schoolgebouwen uit de desbetreffende bouwperiode, gebaseerd op bouwregelgeving en -normen (ECN).
- Vóór 1975 (Energielabel G). Weinig tot geen aandacht voor koudebruggen, slechte isolatie, natuurlijke ventilatie en enkel glas.
- Tussen 1975 en 1992 (Energielabel F & E). Opkomst aandacht voor koudebruggen, invoering nieuwe NEN-normen. Verbeterde isolatie, mechanische afvoerventilatie, invoering dubbel glas en HR ketels.
- Na 1992 (Energielabel <D). Verbeterde isolatie, invoering mechanische toe- en afvoer en veegpulsschakeling verlichting.

Toelichting ambitieniveaus maatregelpakketten
Er zijn maatregelpakketten geformuleerd aan de hand van drie ambitieniveaus:
1. Wettelijk minimum

De Basispakketten bestaan uit een selectie van de erkende maatregelen uit het Activiteitenbesluit Milieubeheer. Deze maatregelen zijn binnen 5 jaar terugverdiend. Daarnaast worden in het Bouwbesluit eisen gesteld. In geval van de oudste gebouwen, kan met een terugverdientijd van 5 jaar niet aan het bouwbesluit worden voldaan.
2. Energieklasse C & Binnenklimaat B

Deze pakketten richten zich op het behalen van Energieklasse C. Deze maatregelen zijn binnen 20 jaar terugverdiend.
3. Energieklasse B & Binnenklimaat B(/C)

Deze pakketten richten zich op het behalen van Energieklasse B. Het duurt ongeveer 25 jaar om deze maatregelen terug te verdienen.

Innovatieve oplossingen
- Onderhoudsbureaus (ESCo's)

Energie Service Companies (ESCo's) zijn onderhoudsbureaus of installateurs, die de installatie, het onderhoud en/of het beheer van installaties verzorgen. De investeringskosten komen voor rekening van de ESCo, die daarnaast energiebesparing garanties geeft (in een energieprestatiecontract). Schoolbesturen betalen de financieringslasten met rente terug.
- Coöperatiemodel

Bij een coöperatiemodel zijn de schoolbesturen eigenaar van een stichting waar de onderwijsgebouwen worden ondergebracht. Integrale verantwoordelijkheid huisvesting en financiering, schaalvoordelen.
- Beheerstichting

Schoolgebouw wordt ondergebracht in een stichting, waar een derde partij eigenaar van is. Dit biedt de mogelijkheid tot een TCO benadering en schaalvoordelen.
- Sale & leaseback (SMV)

Het schoolbestuur draagt het eigendom over aan een aparte stichting, waaruit schoolbesturen het gebouw huren. Dit biedt de mogelijkheid tot TCO benadering. Verduurzaming wordt de verantwoordelijkheid van de stichting.

Vuistregel: *Wie is verantwoordelijk voor welk type verbetering?*

Levensduurverlenging	Gemeente
Energieprestatie	Schoolbestuur
Binnenklimaat	Gemeente
Flexibiliteit	Discutabel (school/gemeente)

Gebruik, Onderhoud en Inregeling van installaties is bepalend voor de levensduur en prestaties. Let op dat dit in orde is. Uitbesteden op afstand is een mogelijkheid.

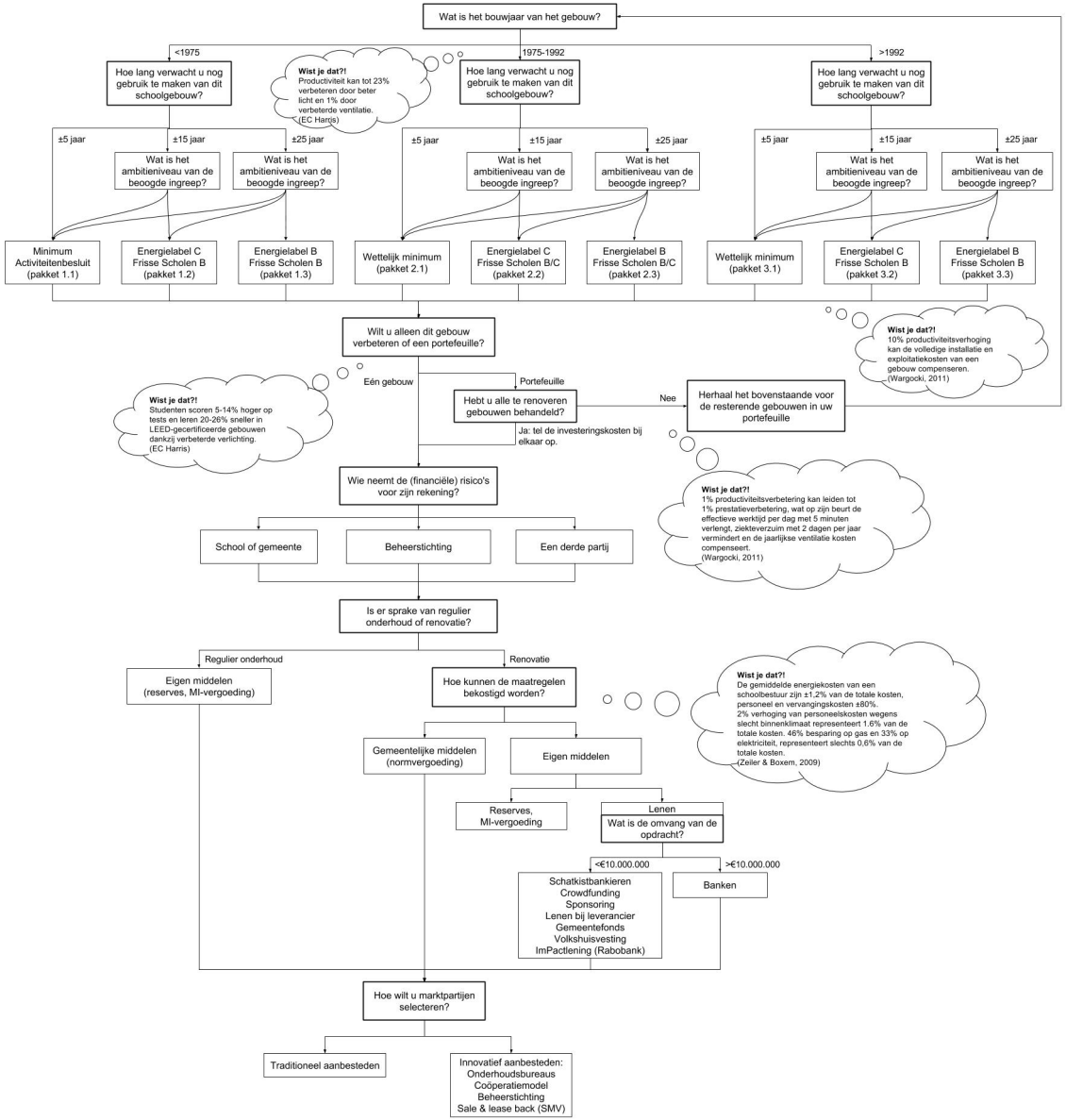

Figure E.4: Decision flowchart, version 4 (final)

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