



SUSTAINABLE BUILT ENVIRONMENT: TRANSITION ZERO

THE UTRECHT SBE16 CONFERENCE
ON 7-8 APRIL 2016

CONFERENCE PUBLICATION

Ivo Opstelten, Ronald Rovers, Nadia Verdeyen & Andy Wagenaar (eds.)



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ON 7-8 APRIL 2016

IVO OPSTELTEN, RONALD ROVERS,
NADIA VERDEYEN & ANDY WAGENAAR (EDS.)

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Final editing and coordination Nadia Verdeyen (HU University of Applied Sciences Utrecht, the Netherlands)
Andy Wagenaar (HU University of Applied Sciences Utrecht, the Netherlands)
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Information Centre of Expertise 'Smart Sustainable Cities'
Research Group 'New Energy in the City'
HU University of Applied Sciences Utrecht, the Netherlands
Padualaan 97, 3584 CH Utrecht
T +31 (0) 88 481 85 22
E smartsustainablecities@hu.nl
W www.smartsustainablecities.hu.nl

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INTRODUCTION



The international conference 'Sustainable Built Environment 2016: TRANSITION ZERO – SBE16' took place from 6-8 April 2016 in the medieval city of Utrecht - the Netherlands, under the auspices of the European Union. The conference is part of the Sustainable Built conference series and is as such considered to be part of the pre-eminent international conference series on sustainable building and construction endorsed by iiSBE, UNEP-SBO and FIDIC. The Utrecht SBE16 conference is hosted by the Centre of Expertise Smart Sustainable Cities of HU University of Applied Sciences Utrecht, in partnership with six Dutch Universities of Applied Sciences (Avans, Saxion, Rotterdam, The Hague, Zuyd, InHolland) and the Utrecht Sustainability Institute (USI).

The Transition Zero conference provides us with a unique opportunity to meet transition professionals in urban sustainability from all over Europe and beyond and to learn about the latest developments and best (inter)national practices in urban sustainability. The rich interest in the conference, made it possible to offer research as well as practitioner-driven tracks on topics related to the conference title. The conference brought together excellent future-minded practitioners, researchers and thought leaders from the R&I community, specialists and professionals on zero energy homes and transition of the built environment.

For the program we put together both an interactive and informative program with showcases at interactive sessions and inspiring keynote addresses and lectures, all in the areas of Transition Zero and a Sustainable Built Environment. In addition to excellent networking opportunities and a taste of local culture, some fascinating insights are offered into what the host city is doing to promote sustainable innovation projects. The conference was preceded on the 6th of April by a session with an introduction on LomboxNet – Vehicle-to-grid, a European first in Utrecht. In the Utrecht district Lombok, the first charging poles that buffers solar power in the battery of an electric car are realized. The next session was about the new Central Station Area in Utrecht. One of the major transformation projects in the Netherlands, building a future that's sustainable: low emission buildings, plenty of pleasant space for bikes, public transport and pedestrians, and solar cells on top of the station platforms. At the end of this first day, the conference participants are welcomed by Lot van Hooijdonck (loco-major), in the Utrecht City Hall.

The conference is chaired on the 7th of April by Frits Verhey, chairman & Director Smart Green Cities at DNV GL and board member of the TKI Urban Energy. The 8th of April is chaired by Jacqueline Cramer, professor of Sustainable Innovation at Utrecht University, the Netherlands, and former Dutch Minister of Housing, Spatial Planning and Environment. The guests are welcomed by Jan Bogerd, chief executive of the board of HU University of Applied Sciences, speaking in name of the organization committee. The plenary program has a line-up of inspiring keynote speakers. Next to this several parallel sessions are offered, focussing on four topics and on European projects. The conference is led by prominent experts:

- *Gerben-Jan Gerbrandy*, member of the European Parliament for the Netherlands - NL
- *Stef Blok*, minister for Housing and the Central Government Sector in the government - NL
- *Larry Brydon*, Vice President at Cricket Energy - Canada
- *Bill Dunster*, principal of ZEDfactory - United Kingdom
- *Ivo J. Opstelten*, professor of New Energy in the City at HU UAS Utrecht, director of the Centre of Expertise Smart Sustainable Cities - NL
- *Emile Quanjel*, professor of Innovative Building Processing & Technology at Avans UAS Breda - NL
- *Ronald Rovers*, professor of Sustainable Built Environment at Zuyd UAS Maastricht - NL
- *Mieke Oostra*, professor of Innovative Technology in Construction at Saxion UAS Deventer - NL
- *Nils Larsson*, executive director IISBE, International Initiative for Sustainable Built Environment - Canada
- *Wim Bakens*, secretary general at CIB, Delft - NL
- *Laure Itard*, professor in Energy and the Built Environment The Hague UAS - NL
- *Talitha Muusse*, Social Entrepreneur
- *Christoph Maria Ravesloot*, professor in Innovation Modelling Renewable Energy at UAS InHolland and Professor in Sustainable Process Innovation and BIM at UAS Rotterdam - NL
- *Maurice van Rooijen*, Entrepreneur, Movares, Jonge Geesten - NL
- *Thomas Rau*, CEO of RAU Architects and one of the leading thinkers on sustainability - Germany

The conference program covers various parallel sessions featuring 35 presentations related to the conference topics Small Urban Area, Upscaling, Circular Processes and Governance. A special session is offered about European projects, with impact on Transition Zero.

On the 8th of April the Young Professionals Event on the Transition Zero Award is organized. In a 'battle' (student competition), between students from 7 Universities of Applied Sciences. Students will present bright solutions in the context of Transition Zero. Months before, they had to submit already their documented proposals and finally five teams are selected to pitch during the Young Professionals Event. The selection has been made by a dedicated panel of experts. The students compete for the Transition Zero Award, the awarding ceremony takes place at the main stage of the SBE16 conference.

To establish international cooperation in the field of professional education is of great importance. Not only to join applied research and development but also to collaborate on pedagogical development related to companies and international activities of other organizations. For this reason, HU University of Applied Sciences Utrecht forms part of CARPE, the first strategic partnership of Universities of Applied Sciences in Europe. It is nice to meet with the representatives of the CARPE partners of Universidad Politecnica de Valencia and of Turku University of Applied Sciences.

Working life and its interdisciplinary needs, forms the base of many presentations. The organization of the SBE16 Transition Zero conference aims to give exposure to the distinctive approach of applied sciences. Urban regions are the key challenge in realizing a sustainable earth. Urban living is growing, the future of manhood depends in an important way on whether and when we are able to reinforce the sustainable development of cities. The city level is nowadays the main level to implement measures. It is inspiring to exchange knowledge and expertise through the different interactive sessions, in which those challenges are exemplified.

This publication offers you the peer-reviewed papers selected by the Scientific Committee of the Conference. The chapters of this publication follows the structure of the four conference topics. I hope and expect that this publication provides inspiration for and information on the state of the art of Sustainable Built Environment, Transition Zero, and that knowledge and experience are useable in joint projects and activities to increase the efforts on the grand challenges of this age.

Utrecht, April 2016

On behalf of the organization of the SBE16, Transition Zero conference

Nadia Verdeyen

Managing Director of the Centre of Expertise Smart Sustainable Cities
HU University of Applied Sciences Utrecht

THEME 1 UPSCALING: FROM PROTOTYPES AND CONCEPTS TO MARKET INTRODUCTION, FINANCIAL & BUSINESS MODELS AND STRATEGY TO MASS MARKET



This track will focus on best practices and experiences with prototyping and demonstration projects to upscaling. Concepts that work in the present with fast retrofitting are creating NetZero houses for future business opportunities. Topics range from how to realise upscaling of demonstration projects towards a sustainable city, towards market introduction and market strategy. There is a special interest for examples of good working business and financing models.

- a. From prototyping and demonstration projects to sustainable areas: the physical challenge
- b. Fast retrofitting concepts for 'NetZero Energy' housing
- c. Market introduction: from prototyping to mass market
- d. Business & financing models for upscaling NetZero energy innovations

CHANCES AND BARRIERS FOR PASSIVE HOUSE RENOVATIONS

There is significant potential for carbon reduction and energy saving in residential buildings. Various market actors are looking for ways to increase the uptake of passive house renovation and its certification.

This study aimed specifically to draw lessons from research projects towards the volume uptake of such renovations in the Flemish Region in Belgium. The empirical part of the study focused primarily on structuring currently perceived supply and demand side barriers and opportunities for introducing nearly zero-energy renovations for single-family houses. As a reflection, the consequences for the market uptake of passive house renovations are discussed.

The demand of homeowners for passive house renovations is still very low and only a limited number of frontrunners has experience supplying such renovations. The top three problems for market uptake of such housing renovation were detected as lack of knowledge, inefficient planning and construction processes and lack of quality assurance. Due to their limited competencies, knowledge or resources small companies do not really have an alternative but to collaborate with other actors.

1 Introduction: Passive house renovations

Europe's buildings are a large energy user, comprising 40% of final energy use and 36% of CO₂ emissions in the EU (EC, 2003; Itard et al., 2008). In the Netherlands, the built environment currently accounts for approximately a third of the total primary energy use. According to Statistics Netherlands (CBS), most of this energy (largely of natural gas and electricity) is used for providing a comfortable indoor temperature and climate (heating, cooling and ventilation), producing hot water and operating electrical appliances.

As space heating dominates energy use in homes located in most European regions, the passive house concept has become a European wide accepted solution to reach a significant energy demand reduction in the built environment (PEP, 2008). In the past few years, passive house principles and components have been successfully introduced in the retrofitting of existing buildings. Depending on the building type, energy savings vary between 80 to 95% (e-retrofit-kit, 2008). The specific heating demand is

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typically reduced from values between 150 and 280 kWh/m²a to less than 30 kWh/m²a. In some cases, the passive house standard for new buildings of 15 kWh/m²a is reached. As pilot projects in different countries demonstrate, these passive house retrofits are economically feasible for a range of building types (e-retrofit-kit, 2008). Achieving the Passive House Standard in refurbishments of existing buildings is not always a realistic goal though, due in large part to unavoidable thermal bridges in the existing structures. Certified renovations according to Passive House principles are therefore usually referred to by retrofitting to the EnerPHit Standard (see www.europhit.eu).

The aim of this paper is to provide an overview of the chances and barriers perceived for the market uptake of passive house renovations in Flanders.

2 Experiences from research projects in Belgium

The 'One-stop-shop' (2012) project investigated opportunities and barriers related to the market development of nearly zero-energy building (nZEB) renovations. A questionnaire led to the identification of various issues that contractors consider important regarding the stimulation of the nZEB single-family home (SFH) market. They indicated strong preference towards awareness rising of customers and companies (see Figure 1).

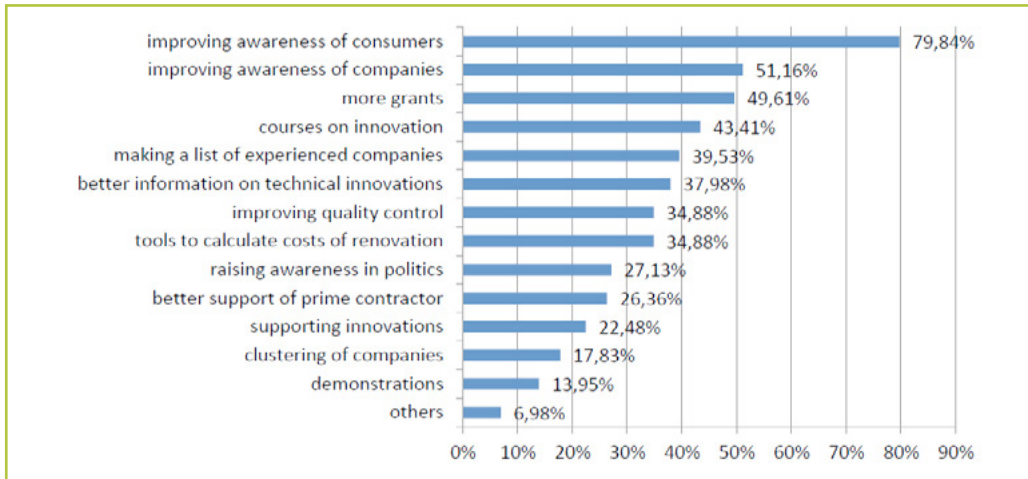


Figure 1: Answer to the question "What focus do you expect regarding the market development of integrated housing renovation?" (139 respondents/contractors; Belgium). Source: ERANET-ERACOBUILD One Stop Shop

The following issues were perceived as particularly problematic, requiring process solutions where better actor collaboration might play a role:

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- Many traditional craftsmen are unfamiliar with the innovations
- Many craftsmen are not used to work together on whole building solutions
- Many craftsmen are involved, often resulting in problematic coordination on site which can result in lower quality
- Disturbance and required effort of the occupants and owners should be reduced

To overcome these barriers, an option was proposed to lift up the level of knowledge of the craftsmen. Also, the systemic use of innovative whole building concepts was found useful, since this can lead to well-coordinated renovation modules with fewer companies involved. A key observation in the project was that, in order to prepare for a growing market, companies must be aware that some customer segments expect one single point of contact to take responsibility, act as project manager, and ensure quality and efficient, rapid execution. Further results of this project can be found in Mlecnik (2012, 2013) and Mlecnik et al. (2012, 2013).

From 1 March 2014 the Flemish federation of architects (NAV), the Flemish contractor federations (VCB and Bouwunie) and the sector federation of consulting engineers (ORI) started a research project entitled 'Working in construction teams, an innovative process' (Werken in Bouwteams, een innovatief proces). This project is supported by the Flemish Agency for Innovation IWT and it aims to optimize construction processes by assembling various types of actors (clients, architects, engineers, key contractors) starting from the concept stage of a construction process. A stronger attention during the design phase is expected to streamline construction processes and to lead to reduced failure costs and better performance guarantees.

The 'construction team' concept is promoted in this project. The happy few who have experience with construction teams are enthusiastic about their own learning process and results. However, they also recognize that expectations from various types of actors can shift in such construction teams. For example, contractors need to do more than calculation and designers need to do more than design. Also, the juridical aspects of construction teams still need some development and construction teams for home renovation are still rare.

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Various Belgian municipalities engage in offering advice on eco-construction to home-owners. For example, the city of Ghent introduced this in 2008 and was surprised by the interest in it: the local building sector could not respond to the demand, e.g. due to the lack of the required skills (EcoAP, 2012). The city of Antwerp does this as well and to cover the demand the city collaborates with two non-profit organisations, one specialized in ecological construction (VIBE vzw) and one in highly energy efficient construction (Passiefhuis-Platform vzw). Brussels Environment has developed a very successful programme for the promotion of sustainable construction in the Brussels Capital Region (Hermans et al., 2012). Architects collaborating in these projects assembled themselves in an informal structure to exchange experiences and knowledge. In the Flemish Region, Verdonck (2012) considered the main barrier to cooperation between firms and extra barriers were noted for small firms (Verdonck, 2012).

3 Further Research Results

3.1 Research approach

This study focused on structuring supply and demand side barriers and opportunities for introducing nearly zero-energy renovations for single-family houses. To understand the concerns of market actors main Flemish stakeholders from various disciplines were invited to discuss qualitative aspects in various working meetings, using focus groups and visual tools for developing businesses and quality assurance in the construction sector developed in the COHERENO project (www.cohereno.eu). These events were designed in such a way as to encourage input from all participants. The results were summarized by the moderators and reviewed by the participants.

3.2 First working meeting

A first international working meeting assembled general knowledge for the nZEB single-family owner-occupied housing renovation sector, which is characterized by small renovation works, laymen and micro, small and medium-sized enterprises. The introducing presentations suggested that the marketing that works for social housing might not work for SFH and that both segments move at a different speed. It is still important in this phase to stick to 'fans' of nZEB renovation. Credible, tangible examples are still needed to convince home-owners. Quality assurance measures before and after renovation were considered important to gain customer confidence. Energy performance contracting was seen as a way forward. During the discussions the attendees agreed that there is a need for independent parties (non-profit organizations, municipalities, and so on) in order to attract the home-owner to consider nZEB renovations. Plans are needed on a municipal level to work out concepts for the market. For example, in Antwerp, the municipality

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offers home-owners free consultations with energy and sustainability advisors. Home-owners have to be facilitated to find the right companies.

Summarizing the results, the Flemish Building Confederation acknowledged that there are three important challenges: finance, quality and collaboration. The affordability of the renovation is a key issue that needs to be eliminated with good communication with banks, installing pay-back capacity and innovation financing. Considering quality issues, there are many labels which make the situation for the home-owner confusing. Regarding collaboration, clear plans are needed to share responsibilities and to determine financial liability of companies. It is important to involve frontrunners in a whole-system approach. The maintenance part is difficult to organize in the private sector.

Better quality assurance was acknowledged as a way to gain customer confidence. Peer-to-peer communication (for example Open House Days) and recommendation (for example a public list of 'recognized' professionals) between home-owners can be very helpful to develop processes for nZEB renovation.

3.3 Follow-up meetings

In the framework of the COHERENO project, a second (national) working meeting took place 6 February 2014 in Westerlo, Belgium. It was attended by about 20 people involved in construction works: contractors (majority of participants), researchers, architects. A third meeting was held with members of Passiefhuis-Platform (various types of companies) which took place 16 June 2014 in Mortsel and which focused on a detected key area of phased renovations.

The discussions went deeper into the topic of quality assurance and certification. Regarding the diagnosis/analysis phase of passive house renovations, the participants noticed that the most important barrier is the lack of sound independent energy advice as a starting point for planning renovation works. For the design/planning phase the participants were mainly concerned about flaws in the concept/plan of the architect and/or the plan. Targets were sometimes badly translated into technical specifications. Concerning execution of works, participants found important barriers to be inadequate product choice, not according to instructions or product guidelines, and lack of on-site coordination and cooperation between various parties involved. Regarding the specific topic of quality assurance, the participants were mainly keen to work in the future more on properly informing all actors in order to agree to deliver an aspired end result (on a trust/informal basis). Also the idea of a quality label for the advisor or the advice found resonance. Working according to codes for good practice was seen as important by the group. Yet, as one group member said, "codes are numerous, and professionals have to know them in the first place".

During these structured discussions similar concerns were expressed by various participants, although the main problem was considered to be insufficient knowledge

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with the architect/advisors on practical issues. However, the feeling is that this is changing and that architects to date are navigating a transition phase (with respect to knowledge acquisition), attending courses and trainings. The knowledge of the actual contractor was also expressed to be a problem. For this problem education and training was agreed as the best and only solution by all group members. Knowledge has to be shared and spread, education has to encompass also learning about existing and new components in the market, and on-site experience – reckoned essential - has to be ensured for instance as part of training programs. Next to that, it appears working in teams or ‘toolbox meetings’ could enhance the learning effect. One participant added the possibility of developing and working according to checklists specific for renovation.

Also, concerns were expressed about how to inform home-owners and how to introduce energy monitoring. To solve this problem mandatory maintenance contracts and providing clients with maintenance protocols - so that they become involved - were discussed.

To address home-owners with financing difficulties, collaboration structures were proposed that address opportunities to show the costs and benefits of a step-by-step renovation and by offering administrative unbundling to apply for loans, grants and so on. In communication the added values (also non-energy benefits) and life cycle cost should be emphasized.

4 Discussion

The start-up of activities in nZEB SFH renovation is not always obvious for companies that don't have experience with passive houses. An important barrier on the supply side is that not many contractors have the proper knowledge to deliver such renovation or to guarantee profitable energy savings. These companies need to understand the necessity for collaboration, the customer values and the role of different actors in collaboration. Also, the companies need to develop their own good examples of demonstration projects to attract customers for nZEB SFH renovation. Collaboration with experienced professionals or consultants makes sense to attract the proper knowledge and to develop first projects. Collaboration between companies requires complementary service portfolios and compatible business cultures. Various types of professionals can collaborate in formal or informal structures: informing actors (for example non-profit organizations or municipalities), consulting actors (for example energy consultants, banks or insurance companies), contracting actors (these can be or not be executing actors), quality assuring actors (to gain customer confidence).

One actor has to take the lead and act as the ‘reassuring’ contact point for the home-owner, maintaining a permanent relationship. Stronger attention is needed in

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order to attract customers, but at the same time advice and design is a service that somehow has to be paid for. From on-going developments, the importance of One Stop Shops and customer web portals, Open House Days and physical renovation stores, is expected to increase.

Similar barriers reappeared in all groups and were also related to construction phases. The top three problems for the market uptake of nZEB housing renovation relate to lack of knowledge, inefficient planning and construction processes and lack of quality assurance. Similar concerns were expressed, such as the lack of training and education of professionals, the attention needed in the design phase, and so on. Due to their limited competencies, knowledge or resources small companies do not really have an alternative but to collaborate with other actors.

It is important to gain customer confidence as an actor operating in the region of the home-owner and think in customer-oriented packages. The home-owner only tends to trust independent advice. Independent knowledge is needed which can be found by collaborating with competence networks and by involving independent/experienced/certified advisers or offering labelled advice.

On the one hand, construction processes can be made more efficient by training all actors involved and regular checks. On the other hand, it is important to have a single trusted contact point for the home-owner; it can be recommended that this person fulfils specified goals (energy performance, timing, information transfer) and manages and coordinates the process. In each case, attention is needed for quality assurance and a performance-based approach, linked to sticks and carrots. The performances should be specified from the beginning and followed up with monitoring.

5 Conclusion

The research showed that – although frontrunners are capable to deliver quality assured passive house renovations – the market uptake for passive house renovation is hindered by various barriers. The supply side for passive house renovation is still suffering from a lack of knowledge, inefficient construction processes, insufficient quality assurance and communication difficulties with home-owners. While collaboration between supply-side actors is seen as a part of the solution to increase competitiveness, many SMEs are still largely unfamiliar with collaboration. The research showed that as the complexity of integrated renovation services increases, a shift in collaboration structures can be expected, likely towards quality assurance and performance contracting.

ACKNOWLEDGEMENTS

- 18 This paper summarizes a selection of findings from the Work Package 3.2 of the COHERENO project, see also: (Mlecnik & Straub, 2014). The COHERENO partners contributed to this report. The COHERENO project is co-funded by the Intelligent Energy Europe Programme of the European Union. The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EASME nor the European Commission are responsible for any use that may be made of the information contained therein.

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ACCELERATING THE SPEED OF NETZERO RENOVATION WITH BIM

In Dutch building process professionals ask themselves if BIM can contribute to acceleration and upscaling of NetZero renovation. It is a problem that the current process of upscaling is going too slow. Case studies show that NetZero renovation is still too expensive and use of BIM is argued to contribute to cost control and to cost reduction. There are reasons to assume that the development of BIM could influence upscaling of NetZero renovation. The variables connected to BIM development are BIM maturity and BIM proficiency. How does the development of BIM relate to the development of upscaling in NetZero renovation? The paper will show how the speed of BIM development was measured by a quantitative analysis. Indicators to measure BIM maturity of organizations and of BIM proficiency of professionals have been found. These indicators are used in a questionnaire, from which strong and weak indicators for BIM maturity and proficiency were elaborated by quantitative analysis. The analysis shows which indicators have a strong positive and negative influence on BIM maturity and BIM proficiency. It can be concluded that BIM is a helpful tool to analyze costs and benefits, that BIM will be helpful in collaboration and will be helpful in calculating energy use during the life cycle of buildings. This supports arguments for a positive effect of BIM development to upscaling in NetZero renovation.

1 Introduction to Dutch BIM NETZERO renovation

The speed of development of BIM can be measured by dividing the increase in maturity by the time between two measurements, just like the speed of a car would be calculated by dividing the distance traveled by the time of travel. BIM maturity research has been executed by scientists Sucar before (2008, 2010). In the Dutch context BIM maturity research has been executed by Sebastian & Berlo (2010) and Berlo (2013). In Dutch NetZero renovation BIM will be expected to minimize risks during design and construction by supporting collaboration between parties and persons. In BIM it is possible to test the process of design and construction virtually before going to actual construction at the building site. Energy calculations can be executed fast and accurately. Two variables are connected to BIM development: BIM maturity and BIM proficiency. BIM maturity relates to organizations, while BIM Proficiency relates to individual professionals in these organizations. The main

question in this paper is how the development of BIM can be related to upscaling in NetZero renovation? The goal of the research is to discuss arguments that support a positive effect of using BIM to speed up upscaling of NetZero renovation.

1.1 BIM in Dutch Building Practice

To measure the speed of BIM development a quantitative analysis can put out every year. To make the measurement work properly, indicators are used in a questionnaire. Every indicator represents a factor influencing the successful use of BIM by organizations (maturity) and of BIM by professionals (proficiency). Through the statistics in the quantitative analysis strong and weak indicators for BIM maturity and proficiency are elaborated. According to Stel, indicators can be found in four types (Stel 2015):

Product driven: BIM hard- and software indicators

Process driven: organizational indicators, how is BIM used in organizations

People driven: professional proficiency indicators, how do professionals cope with BIM

Personal driven: background and motivation to work with BIM

According to research the quality of the collaboration between professionals in a team is influencing the project results the most (Ravesloot 2016). This conclusion was found by asking the professionals themselves. BIM makes it easier to collaborate in project for NetZero renovation, because information is equally available to all team members in the same quality and at the same moment. This is particularly important in avoiding misunderstandings during execution and in logistics in the construction phase.

A benefit of using BIM in designing is in analyzing costs and benefits related to energy saving and production of renewable energy in NetZero renovations. If the costs can be estimated without the usual margins for possible risks during construction, these can be compared to benefits more precisely. It was found that the type of contracting also relates to the costs and benefits in sustainable building in general. Cost benefit analysis with input for energy use can show that integrated contracts can be more beneficial, because the investor is also the party that gains from the benefits. According to Ravesloot en Huovila (2012) BIM is best used in service driven procurement and in integrated contracts, which are also favorable for sustainable development in general. BIM use in procurement process focussing on price only, will not support sustainable development in general and will therefore not support NetZero renovation.

1.2 Maturity and proficiency

22 In scientific literature indicators for BIM maturity in organizations are mentioned. The ten most frequently mentioned are listed below (Bruin, Rosemann, Freeze & Kulkarni 2005; Coates, Ariyici, Koskela, Kagioglou, Usher & O'Reilly 2010; Deutsch 2011; Azhar 2011; Khosrowshahi & Arayici 2012; McCuen 2012; Siebelink, Adriaanse & Voordijk 2015):

- Support of the management for using BIM
- Resources (finances, hard- and software etc.) available for using BIM
- Presence and use of BIM in vision and strategy
- Presence and use of agreements
- Presence and use of BIM roles and functions
- Awareness of the advantages and disadvantages of BIM
- Share information among colleagues
- Communicate with open files (IFC)
- Presence and use of a BIM protocol
- Attendance BIM-champion in the organization

Indicators of proficiency on an individual level are less mentioned but still available. The ten most frequently mentioned are listed below (Succar 2010; Succar 2012; Miglinskas 2013; Succor 2014a, 2014b, 2014c, 2014d, 2014e):

- Knowledge about the definition of BIM
- Experience with modeling
- Individual and group motivation
- Take action to improve implementation of BIM
- Intern and extern collaboration

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- Experience change in function is useful
- Take action to learn about BIM
- Make others enthusiastic for using BIM
- Help colleagues with using BIM
- Share information with BIM

These most commonly mentioned indicators in literature were verified and substituted with indicators retrieved from interviews with Dutch BIM experts. With those substitutions the result of the research will be more valid for the Dutch context of design and construction processes.

2 Research methodology

The research is based on a quantitative survey amongst Dutch building professionals, actively participating in BIM development. The survey was put out amongst professionals in the Dutch building industry in general, mostly between thirty and forty years old, working for big construction companies, with more than 500 persons working in one company. Although the analysis is done qualitatively, the results have to be seen as tentative. The survey is only an exploring research, because of the small number of respondents in a sample amongst non homogeneous professionals in the Dutch building practice.

2.1 Quantitative research on BIM maturity and proficiency

All indicators for measuring BIM maturity and proficiency in BIM were put into an online survey. The results were analyzed by statistics in SPSS Statistics version 22. The most important results were the distinction of strong and weak indicators and the distinction of correlations between indicators. These two distinctions would give an accurate view on the functioning of BIM in the Dutch construction industry and the potential connection to NetZero renovation. The assumption in the research is that the context of Dutch NetZero renovation is comparable to the general Dutch context.

2.2 Connection to NetZero Renovation

NetZero renovation in the Netherlands has been developing since the first NetZero house was renovated in 2000 as part of an extensive study on energynutral housing (Ravesloot 2005). The technical challenge is not only in calculating the energy use to

NetZero without inaccuracy between calculation and reality. There is also a challenge in integrating the right technical components to the existing technical state of the houses. According to Ravesloot (2005) integration is depending on the proper calculation of the technical components in line with an optimal cost-benefit analysis. Here BIM can be of great use. With BIM these calculations can be made faster, with the same accuracy and accountability and with more transparency for project team members. This way BIM is providing information for decision making. Being faster supports minimizing of risks during construction. With BIM the combination of many technical solutions can be calculated against many economical scenarios. The time for performing these calculations can be minimized as well. The use of BIM will also support collaboration in the NetZero renovation project team, in the short term as well as on the long run. The connection to NetZero renovation however was not specifically researched for this paper.

3 Execution of Quantitative Research

The connection between BIM and NetZero renovation is explored in this paper. Although indicators are representing the Dutch building industry in general, they may be relevant for NetZero renovation industry specifically too. In this paragraph arguments for this relevancy will be stated. The survey analysis is based on 75 completed surveys, representing professionals of the Dutch building industry.

3.1 Results Dutch BIM maturity

A first complete quantitative analysis on BIM maturity and proficiency with BIM in the Dutch context was first established (Jansen de Wit 2014, Stel 2015). The results show that the Dutch construction industry is developing BIM as part of design and construction processes fast. Five classes are distinguished:

Class 0	0 points	no BIM
Class 1	1-27 points	BIM staller
Class 2	28-54 points	BIM starter
Class 3	55-81 points	BIM mature
Class 4	82-108 points	BIM sprinter
Class 5	109-135 points	BIM spreader

The classification above shows the classes of BIM maturity from the quantitative research in Dutch building industry. Every indicator has one or more points to score. More points means more indicators, which is a measure for higher BIM maturity. The scale is only temporary valid, since the development of BIM is still going on. New indicators will be needed to measure future BIM maturity.

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Organizations in class 0 have no idea what BIM is about. The class 5 performing organizations are constantly improving their projects with BIM. The classes do not refer to proficiency in BIM for individual professionals within these organizations.

In the results of a second research there are nine indicators with a high coefficient of correlation with BIM maturity (Stel 2015). The results are based on 72 completed surveys amongst respondents from the Dutch building industry:

No.	General indicator for BIM maturity	Indicator for NetZero renovations
1	Use BIM in organizations	x affects renovation costs positively
2	Work according BIM agreements	x affects renovation costs positively
3	Work according BIM roles	x improves process of collaboration
4	Work according a BIM protocol	x improves process of collaboration
5	Using BIM in primary business processes	o
6	Make agreements about information processes	x avoids failure, reduces risks
7	Share information	x avoids failure, reduces risks
8	Use open files (IFC)	o
9	Keep employees informed of the latest BIM successes	o

The list above shows the indicators for BIM maturity as found in the Dutch building industry by Stel (2015). The strongest correlated indicator is mentioned first. The x and o show if an indicator can be of importance in NetZero renovation projects too. According to literature on BIM and effects of BIM on the design and construction process, A) renovation costs would be reduced, affected positively, B) improve the process of collaboration, reducing time spent on the process, hence reducing costs and C) avoids failure due to lack of information and uncoordinated information processing (Azhar S. 2011; Coates et.al 2010; Miglinskas et al. 2013).

A strong positive correlation can be found for the indicator of consciousness for BIM in the organization. If professionals are not aware of the benefits of BIM, the maturity will probably be low.

3.2 Results Dutch BIM proficiency

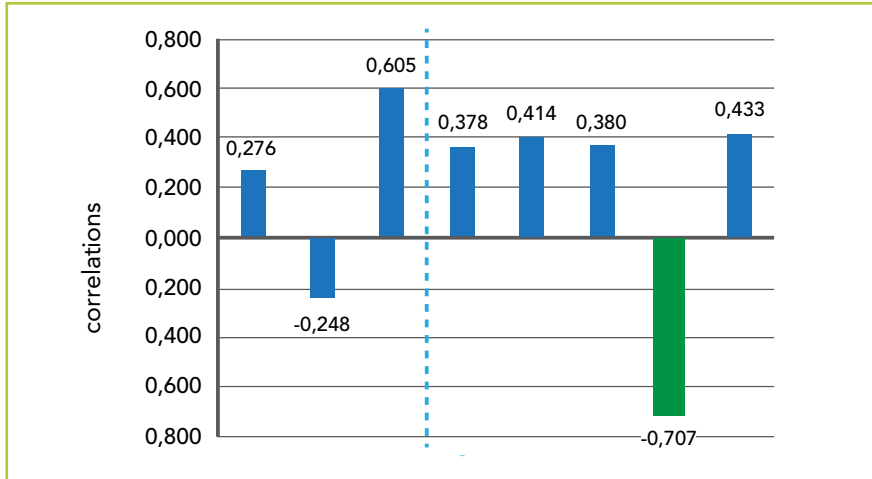
Stel also put out questions in the survey that measure BIM proficiency amongst Dutch building professionals. The same 72 respondents answered questions about their personal proficiency working with BIM.

Most strong correlated indicators for proficiency with BIM are (Stel 2015):

26	No.	Indicator BIM proficiency	Indicator NetZero renovations
	1	Communicate in organization	x communication in general
	2	Share information	x communication in general
	3	Use BIM for better internal collaboration	x communication in general
	4	Help colleagues with using BIM	x communication in general
	5	Use BIM for better external collaboration	x communication in general
	6	Have experience with BIM projects	x communication in general
	7	Make other enthusiastic for using BIM	x communication in general
	8	Communicate outside organization	o
	9	Take action to improve BIM implementation	x communication in general

The strongest correlated indicator is mentioned first. The x and o show if a possible indicator that can be related to NetZero renovation projects. The possibility is based on the assumption that improvement in communication and collaboration in general will contribute to better project results in general, also in case of NetZero renovation. The mechanism in improvement of communication and collaboration within BIM is based on the impossibility of participants to have and use power due to lead in knowledge and information. BIM provides information for everyone involved instantly and equally (Barlish Sullivan (2012)).

A strong negative correlation was found for professionals without a BIM role in their project work. According to Stel, they can hardly be proficient in BIM if not having a clear BIM related role. A strong influence of high proficiency in BIM on the product quality can be expected (Stel 2015). Therefore a high BIM proficiency can support upscaling NetZero renovation, if BIM is used in the process of design and construction.



The graph above shows the correlation between eight indicators used in the survey around the negative correlation of not knowing the BIM role for a professional in the Dutch building industry (Stel 2015): 1 working in several sectors of the Dutch building industry, 2 company size, 3 multiple purpose for BIM use, 4 BIM coordinator, 5 BIM manager, 6 BIM director, 7 no BIM role, 8 knowledge of BIM.

3.3 Possible meaning for NetZero Renovation

One of the most challenging problems in NetZero renovation is the integration of technical components in existing buildings. It makes sense to make custom integrated designs for every type of building separately, if you do not have to worry about the price. This, however, is not the case. Customization drives up the margins used to cover for unexpected risks because processes are less automated and less standardized. The houses of private owners however, do differ more than they have in common, making one technical integrated solution for as many types of houses a challenge. Rented houses from housing corporations on the other hand, do have more similarities, the adjustment of one technical integrated solution for as many types of houses might be less of a challenge. The challenge here is in the adjustment of general solutions to specific tolerances in measures of the individual houses and in adjustment to the individual specifications of tenants.

The common approach is to design industrially produced standard components, that can easily, and with only little extra costs, be adjusted to local circumstances, no matter what the tolerances and individual specifications are. Such a process of industrialized can be supported with BIM. BIM supports testing the tolerances of the standardized components with the components in the existing building.

BIM supports testing virtually. Parallel to this, the logistics and costs can be optimized. The virtual testing will make the team aware of the difficulties that lie ahead during construction, without calculating these risks in the price of the product (Stoele 2014).

4 Discussion on the results

From the quantitative research nine most influential factors for potential successful integration of BIM with NetZero renovation were retrieved. The same way nine most important factors influencing proficiency in BIM by professionals involved in NetZero renovation are retrieved.

4.1 Discussion Dutch BIM Maturity

From the nine strongest BIM indicators for three indicators it can be argued that there is no immediate integrative connection with NetZero renovation: Using BIM in primary business processes (5), integration of BIM with NetZero renovation would suggest that NetZero renovation is already part of or integral part of a primary process. Looking at the small number of cases of NetZero renovations in the Netherlands, it is logical to conclude that primary processes in the Dutch building industry are not supporting NetZero renovation.

The use of open files (IFC) (8), the exchange of information through the IFC (industry foundation class) format, does not change if information about NetZero renovation is transferred. So IFC can not have an integrative connection.

Keeping employees informed of the latest BIM successes (10), BIM use and progress in BIM use will be related to many kinds of projects, other than and next to NetZero projects, otherwise BIM would be tailored for NetZero renovation. Which it is not, BIM is for general improvement of design and construction processes in building industry (Nederveen Tolman 1992).

These three are not influencing successful collaboration in NetZero projects. NetZero projects can be kept outside primary working processes within companies. This is called little BIM project environment. In these project environments exchange of files does not need to be done by IFC, other employees of the company need not to be involved directly. The other six indicators on the other hand can improve the typical fail factors in NetZero renovation.

4.2 Discussion Dutch BIM proficiency

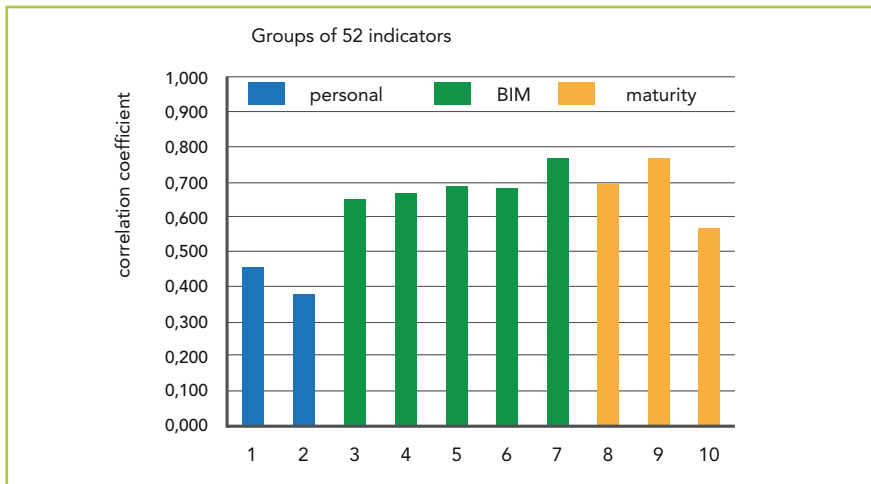
In the list of nine strong indicators for proficiency in BIM only one does not relate directly to NetZero renovation projects. 'Communicate outside organization' is not necessarily needed for a BIM success.

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Industrialization and automation of NetZero renovation products can be optimized within a project environment. Since collaboration in general is a problem in Dutch building industry, this might be the same specifically in NetZero renovation projects. BIM can support better collaboration if carried out by highly BIM proficient professionals. An advantage can be created by working in a little BIM project environment. Working in a little BIM, makes it also possible to change the workflow from orientation on individual projects, which is the case in current NetZero renovation, towards a workflow that is managed from a product line. Project management will have to adapt to that change. BIM can support that change.

An interesting result from the second survey by Stel is that personal BIM proficiency has a similar influence on the overall BIM maturity of project environments as BIM maturity in organizations.

The graph shows the correlation coefficient in ten groups of indicators from the perspective of BIM maturity in organizations and personal BIM proficiency. The group of personal indicators, in blue, is almost as strong as the group of yellow maturity indicators, compared to the BIM indicators in green in general.



The graph above shows ten groups, covering 52 indicators used to measure BIM maturity and BIM proficiency in the Dutch building industry by Stel (2015): 1 personal indicators, 2 company indicators, 3 data structure, 4 people and culture, 5 structure of the organization, 6 partnering, 7 strategy, 8 background, 9 method of collaboration, 10 motivation.

5 Conclusion BIM and Dutch NetZero Renovation

30 From the discussion it is understood that BIM maturity and BIM proficiency in general terms can be connected to the specific context of Dutch NetZero renovation. Most strong indicators for Dutch NetZero projects with BIM will be the improvement of collaboration with the product team. This is consistent with observations of project managers in the building industry in general. The change from project based management to product based management can be supported by BIM, provided that partners and participating professionals know their role in BIM and know how to use the benefits from working with BIM. From this result it can be concluded that the use of BIM in NetZero renovation will speed up the upscaling considerably.

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INSITER SELF-INSPECTION METHOD AND INSTRUMENTS TO ENSURE OPTIMAL PERFORMANCE OF PREFAB RETROFITTING SOLUTIONS

The benefits of prefab retrofitting solutions for NET Zero Energy buildings (such as prefab components for building envelopes, windows, equipment) are at risk because of bad implementation during the construction processes. As a result, the energy-efficiency potential as designed will not be realised. The European Horizon 2020 research project INSITER develops a quality assurance method that closes the performance gap between design and construction.

This paper reports on the first phase of such a method, being a desk research to identify the most frequent construction errors, state-of-the-art diagnostic instruments to detect the errors and suitable standards for performance control.

1 Introduction

The EU authorities have set ambitious targets to reduce CO₂ emissions to 20% below their 1990 levels (CEC, 2007). The building sector is the largest energy user in Europe, consuming 39.8% of the total energy in the EU-27 (European Union, 2012). Therefore it is an important sector to focus on, regarding its large reduction potential. With the revised 2010 Energy Performance of Buildings Directive (EPBD) and the 2012 Energy Efficiency Directive (EED), the European Commission has laid down a new set of energy efficiency standards, therewith improving the energy performance of buildings in all EU Member States, both new built and existing ones.

To reach the EU CO₂ emission reduction targets and meet the energy efficiency standards, the European Commission supports innovation in energy saving in construction, among others by research grants. The INSITER project was funded under the Horizon 2020 research program.

1.1 The INSITER project

INSITER is a research project that runs from November 2014 till October 2018. The project aims to eliminate the gaps in quality and energy-performance between design and realization of energy-efficient buildings based on prefab components.

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
INSITER self-inspection method and instruments to ensure optimal performance of prefab retrofitting solutions	Dr Martin Roders MSc Dr Arch Emanuele Piaia Dr Rizal Sebastian MSc	DEMO Consultants Delft, the Netherlands Ipostudio Architetti SRL Florence, Italy DEMO Consultants Delft, the Netherlands	martin@demobv.nl +31 6 10436652

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During construction, each actor of the highly fragmented value-chain (Egan, 1998), must ensure that his contribution fits into a quality framework defined collectively at the design level. However, the targeted performance aimed at during all stages of the design process are hampered by critical shortcomings during on-site construction and refurbishment that cause a lower built-quality and sub-optimal energy-saving in the building lifecycle. Through self-inspection techniques, based on intuitive and cost-effective Augmented Reality (AR), INSITER aims to leverage the energy-efficiency potentials of buildings based on prefab components, not only NET Zero Energy buildings but also other types of buildings, as well as refurbishment and maintenance projects. It will scale-up the use of BIM for standardised inspection and commissioning protocols, involving all actors in the value-chain.

In short, the activities in the project focus on developing (Sebastian et al., 2015):

- a method for self-inspection, containing an explanation of which construction workers should carry out what activities for quality control at which moment during the construction works;
- hardware tools that can be used for self-inspection, such as laser scanners for the correct positioning of building elements. INSITER aims to resolve the current limitations of existing technologies that are constrained by the need for continuous updates and relatively low speed and accuracy of the data acquisition.
- software that allows the previously mentioned self-inspection tools to communicate with each other by means of a smart Application Programming Interface (API) and data integration with a cloud-based Building Information Model (BIM).
- a Building Information Model for lifecycle performance and asset management of energy-efficient buildings while connecting a virtual model and the physical building in real-time.

The research outcomes of the above named activities will be validated and demonstrated in real-time use cases.

By the end of the project, INSITER should be able to verify the estimated energy performance based on the design prior to construction and be able to anticipate, prevent and resolve performance and quality gaps. Construction workers, supervisors,

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clients and end-users should be provided with practical method and training to perform self-instruction & self-inspection and a set of intuitive, robust and cost-effective measurement instruments with BIM & AR to perform self-instruction & self-inspection should be developed.

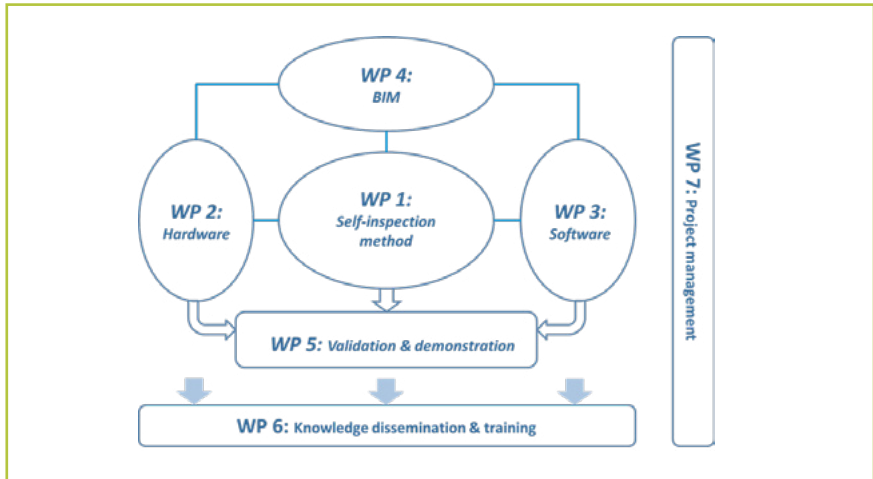


Figure 1: INSITER project structure (Source: Sebastian et al., 2015)

2 Methodology

A desk research was carried out to identify the most frequent construction errors and to find suitable standards for performance control of the construction process and the finalized building components that can be taken as a reference for the development of the INSITER self-inspection method. In this paper the errors and standards are solely listed, because it reports on the data acquisition which has taken place. Further developments and the relationships between errors and standards will be elaborated in upcoming papers.

The review on the construction errors was done by experts from four companies of the consortium that are dealing on a day-to-day basis with construction projects, being an engineering firm from Italy, architect's offices from Germany and Italy (all SMEs); and a Spanish construction company (Large Industry). The review resulted in a list of 96 errors, which after deliberation among the consortium experts was reduced to 12 crucial errors for the building quality and energy performance of the building envelope (Di Giulio et al., 2015).

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36 The collection of the standards was a joint effort of in total ten partners from the Netherlands (4), Italy (3), Spain (2) and Germany (1). In total 76 standards were found relevant for self-inspection, of which few were selected for further analysis because they fit best to the INSITER objectives related to self-inspection of prefabricated building components.

3 Results

3.1 Construction errors

Considering the industrialized building realized with prefab components several errors can be committed during the construction and manufacturing task. The subsequent list proposes the main errors and the problems derived:

- Offsite manufacturing in conflict with the design. The manufacturing components of the building envelope are different (e.g. incoherent surface finishing or materials, improper inner materials of sandwich panels, incongruent geometric dimensions, etc.) in comparison to the final technical drawings and specifications elaborated by the design team.
- Poor manufacturing of the building components. The incorrect technical manufacturing of the envelope building components can cause defective components characterised by technical attributes differing from the expected performances.
- Onsite manufacturing in conflict with the design. The building envelope construction is different in comparison to what was proposed and does not follow the specifications of the final design.
- Assembly of damaged building components. The transportation of the building components, the movement as well as the incorrect stock on-site could cause damage to the components (breakage, surface abrasion, etc.).
- Incorrect or mistaken assembling of the building components. The incorrect assembly of the building components, particularly concerning the joints between the various parts that link the building façade and the roof (e.g. windows/doors to façade, panel façade to panel façade, wall to slab, and façade to roof) cause several building defects.



- Poor component locations or improper installation. A correct installation of building components is extremely significant in order to maintain the expected performance of the construction.
- Misinterpretation or incorrect use of the documentation (e.g. technical drawings). The technical knowledge background of the construction workers and the understanding of the final design elaborated by the design team are very important for the correct realisation of the building.
- Omission or assembly of building components differing from the final design. The assembly of building components differing from the technical design (e.g. different sandwich panel, different inner insulation, different windows) will alter the energy performance of the building.
- Geometric problems of the building components. To seal the building envelope it is necessary that all building components are properly realised from the geometric point of view.
- Installation of unsuitable material. The monitoring of the component quality that arrives on-site is very important to preserve the original requirements.

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- Windows and doors incorrectly sealed on-site. The correct assembling of windows and doors on external walls as well as skylights in roofs is crucial to reduce the airflow.
 - Irregular site inspection by the project manager. Regular inspection on the building construction site by the project manager is fundamental to control the realisation of the building quality.

3.3 Condition assessment and inspection standards for building components

This section lists and gives a short explanation of the standards most relevant for the INSITER objectives:

- NEN 2767-1:2011/C1:2013 NL - Condition assessment - Part 1: Methodology and Part 2: Lists of faults describes a method to establish the technical quality of building and installation components univocally. Relevant for INSITER:
 - The building is logically subdivided in components
 - Classification of the importance of the defects
 - Classification system for severity of defects in condition
 - Guidelines on determining the extent of the defects
 - Condition ratings, one score based on the importance, severity and extent of the defects
 - Visual inspections, with use of measuring tools and other equipment at small scale
 - Inspections carried out by trained inspectors
- NEN 3682:1990 NL - Dimensional control in the building field - General rules and guidance sets generic rules for dimensional control of building elements, positioning on-site of building elements, spaces and joints. Relevant for INSITER:
 - Instructions on positioning of measurement points
 - Instructions on registration of measurements
 - Instructions on operation of tools
 - Definitions of deviations
- UNE 85247-11 Windows and doors. Watertightness. Site test defines the method to use in order to identify water penetration points in windows and doors once installed in a building. Relevant for INSITER:
 - Instructions on Initial assessment
 - Instructions on positioning of measurement points
 - Instructions on registration of measurements

TITLE
INSITER self-inspection
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AUTHORS
Dr Martin Roders MSc
Dr Arch Emanuele Piaia
Dr Rizal Sebastian MSc

ORGANIZATION
DEMO Consultants
Delft, the Netherlands
Ipostudio Architetti SRL
Florence, Italy
DEMO Consultants
Delft, the Netherlands

MAIL ADDRESS
martin@demobv.nl
+31 6 10436652

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- DIN 18197, April 2011 - Sealing of joints in concrete with water stops applies to planning, assessment, treatment, processing and installation of water stops used for sealing against ground moisture, non-pressing or pressing water as well as the termination of joints. Relevant for INSITER:
 - Instructions on positioning of measurement points
 - Instructions on installation of measurement points
 - Instructions on monitoring and documentation
 - Instruction on deformation stress of measurement points
- NEN 6059-1:2015 NL - Assessment of fire safety of buildings - Part 1: Initial assessment of fire safety of buildings; Part 2: Condition assessment of fire safety of buildings is a tool to inspect existing building uniformly on the aspect of fire safety. Relevant for INSITER:
 - List of items to review (Initial assessment)
 - Definitions on the size of the occurrence of the error
 - Definitions on the character of the error (severe/not severe; specialism, knowledge or equipment needed to correct the error)
 - Classification for the importance of the error
- EN 1330-1:2014 – Non-destructive testing – Terminology - Part 1 and 2: List of general terms sets the general terms used in non-destructive testing, but which stem from other fields (electricity, vacuum technology, metrology, etc.) and apply in non-destructive testing. Relevant for INSITER:
 - List of general terms that can be used to set up inspection procedures
 - Definition of the basis of the common scientific vocabulary to be adopted
- EN-EN-13187 Thermal performance of buildings - Qualitative detection of thermal irregularities in building envelopes - Infrared method specifies a qualitative method, by thermographic examination, for detecting thermal irregularities in building envelopes. Relevant for INSITER:
 - Description on reporting and the presentation of results
 - The results obtained by means of this method have to be interpreted and assessed by persons who are specially trained for this purpose
 - Determination of the location of thermal irregularities and to the location of air leakage paths through the enclosure

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The analysis of the condition assessment and inspection standards has led to the following key elements that should be taken up in the INSITER inspection protocols and guidelines:

- A clear definition of the building components and key data to be assessed (window, or façade element etc.)
- Common vocabulary
- Description of the diagnostic instrument per inspection item
- Instructions on the operation of diagnostic instruments
- Instructions on the positioning (and installation) of measurement points
- Instructions on how to register and report the measurements
- Description of how and by whom measurements are interpreted: software based, e.g. clash detections, or with support of (trained) inspectors

4 Discussion

As a part of a larger research project, this paper has identified frequent construction errors in prefab construction, as well as the relevant condition assessment methods that can be used for the prevention of the errors. In the next phases of the research the quantitative boundaries shall be defined that indicate to which extent an imperfection resulting from the production process unacceptably compromises building quality or energy performance. In other words, it will be defined when an error results in unacceptable consequences, because in that case it needs to be corrected. For example, if a joint between two building components is not completely closed (construction error), this does not necessarily mean that it leaks air, or that it leads to such a loss of energy performance that it justifies rework (implying higher costs etc.).

The follow-up research shall establish the width of the joint that leads to unacceptable loss of performance. In the above example, it could be that every joint >2cm is considered an error, <2cm is no error.

Moreover, a Stakeholder Analysis shall be carried out, to determine which actor is responsible for deciding on the tolerance boundaries. For example, the engineer responsible for the energy calculations can indicate when unacceptable heat loss occurs, while an architect focuses on the aesthetical and functional performance of the building.

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In the research stages thereafter, it shall be defined who will detect the error in the most efficient way and at which moment during the construction process by means of self-inspection. The outcomes of these stages will be implementation guidelines. In the meantime the development of INSITER diagnostic instruments, software and BIM takes place so that the persons in the field are able to measure if the error is really an error. Taken again the example of the joint between two building components, the tools need to be able to measure the distance (in cm) between the components, so that it can be verified whether the components are placed correctly (joint <2cm) or not (joint >2cm).

Regarding the bigger picture of the whole project, developments are made at hardware level, the tools that will be used to measure and detect errors; at software level, to make the hardware tools communicate with each other and produce information for decision support and at BIM level to be able to monitor the real-time progress and quality with the simulated progress and quality.

5 Conclusion

Self-inspection will not disrupt on-site working processes by additional effort; it will save time and costs by making the processes efficient and accurate. The INSITER methodology supported by the relevant measurement and diagnostic instruments will close the gap between design and realisation in new construction, refurbishment and maintenance projects. The real-time INSITER self-inspection concept has a strong contrast with the traditional approach of 'post-inspection'. These are currently done by an observer/auditor/controller after a working process is finished. In such a traditional approach, errors and defects are always discovered 'just too late', followed by a long and difficult process to point out 'who to blame' and to decide 'how to fix the mistakes done'. INSITER will prevent costly repair actions and make the process transparent regarding liability, accountability and insurance.

ACKNOWLEDGEMENTS

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INSITER self-inspection
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AUTHORS
Dr Martin Roders MSc
Dr Arch Emanuele Piaia
Dr Rizal Sebastian MSc

ORGANIZATION
DEMO Consultants
Delft, the Netherlands
Ipostudio Architetti SRL
Florence, Italy
DEMO Consultants
Delft, the Netherlands

MAIL ADDRESS
martin@demobv.nl
+31 6 10436652

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RESULTS FROM FIRST "NETZERO ENERGY" PROJECTS IN THE NETHERLANDS

Building companies in the Netherlands found a way to refurbish existing houses to net Zero Energy (nul op de meter), within a week, with a 30-year builders' guarantee, economically sound for the consumer even without subsidies. NetZero Energy houses within this article produce the same amount of energy as they use.

The Dutch innovation program "EnergieSprong" (literally: Energy Leap) started in 2010 to stimulate and challenge the Dutch market. Initially, subsidies for large scale renovation projects (30 houses or more) with total (primary) energy-use savings from 45% up to 60% and 80%, were made available. Around 2013 the first initiatives aiming for guaranteed net zero energy started.

All these projects are extensively monitored by EnergieSprong. Not only technical performance is measured, also the process from the renovation as well as the opinions of people who live in these houses are monitored. The first renovation projects were recently finished (in 2015) and some are still being realized or prepared. Results from these projects are being gathered and collected for further analysis. This paper provides an overview of intermediate results of this monitoring by the consortium of TNO, Van Beek and Rigo.

Initial results shows in a first pilot that the promised NetZero Energy ambitions have been met and that residents are satisfied. NetZero Energy retrofits have become a new reality.

1 Introduction

Building companies in the Netherlands found a way to refurbish existing houses to NetZero energy (nul op de meter), within a week, with a 30-year builders' guarantee, economically sound even for social housing without subsidies.

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The Dutch innovation-implementation program "EnergieSprong" (literally: Energy Jump) started in 2010 to stimulate and challenge the Dutch market, funded by the Ministry of Housing and Civil Service. Initially, subsidies for large scale renovation projects (30 houses or more) with total (primary) energy-use savings from 45% up to 60% and 80%, were made available. Around 2013 the first initiatives aiming for guaranteed NetZero energy started.

All these projects are extensively monitored by EnergieSprong. Not only technical performance is measured, also the process from the renovation as well as the opinions of people who live in these houses are monitored. This paper provides an overview of intermediate results of this monitoring by the consortium of TNO, Van Beek and Rigo. The first renovation projects were finished recently (in 2015) and some are still being realized or prepared. Results from these projects are being gathered and collected for analysis. Five of these project are used for results described in this paper. These projects are: Kerkrade, Ulft, Montferland, Amsterdamse Buurt (Haarlem) and Rijswijk Buiten.

This contribution presents an overview of the monitoring results within this program. Technical performance, the renovation process and inhabitants satisfaction will be presented and compared to the theoretical performance of the concepts. Questions as to what has been learned, what is important for a good concept in practice and what can be improved to realize it, will be answered.



Figure 1: Kerkrade, where passive cooling measures were applied in the shape of an overhang, night ventilation grid and improved insulation

Builders who wish to realize energy efficient and/or NetZero Energy housing concepts face a number of challenges. Both on a social, economic and technical level, there is work to be done. There has been some pioneering going on, and we can learn from that.

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It is not within the scope of this paper to cover all aspects of the social, economic and technical topics. Only the most important aspects that appeared from the monitoring program will be shared and discussed in this overview paper.

Although the amount of dwellings per project is limited the evidence is not conclusive. But it certainly gives an indication if an approach is interesting.

2 Energy concept

Although a high energy ambition can be realised in different ways, the dominant concept used by building companies for industrialisation (both newly built and renovation), consists of a highly insulated and air tight building skin, in combination with an all-electric heat pump driven energy system. A full roof PV system or a solar heat-PV combination provide the required local energy production for the average building related energy demand and the coverage of the energy demand stemming from the average use of house hold appliances. Sometimes measures are applied to reduce energy use of household appliances as vouchers for A++ appliances.

3 Construction quality

Airtightness, noise pollution and draught as a result of the ventilation system are critical factors for achieving the promised energy and comfort performance.

Project name	Design airtightness $Q_{v,10}$ [cubic dm/sq. m]	Actual airtightness $Q_{v,10}$ [cubic dm/sq. m]
Kerkrade	0.15	0.41 – 0.51
Uift	0.20	0.34 – 0.42
Amsterdamse buurt	0.625	5.2
Montferland	0.40	0.43 – 0.58

Table 1: Difference between design point of departure airtightness and actual airtightness.

1 cubic dm extra equals around 10 kWh extra heating demand. Project name Design airtightness $Q_{v,10}$ [cubic dm/sq. m] Actual airtightness $Q_{v,10}$ [cubic dm/sq. m]

Due to air leaks and unbalanced heat recovery systems, the houses use more energy than is contractually promised. Because of the noise, residents sometimes even turn of the heat recovery system. This possibly explains the additional window use for

ventilation, which in turn leads to additional energy loss. With a heat pump drive energy system, this could even lead to loss of thermal comfort because there is insufficient capacity.

Air leaks are often found in the same spots, which therefore require special attention. The most common air leaks are the chimney and the roof ducts, windows, window frames and doors. Airtightness tests, applied before finishing in order to detect air leaks is a simple way to minimize air leaks and thus to obtain the contractual energy reduction. Obtained airtightness in practice is often not as good as expected, see table 1.

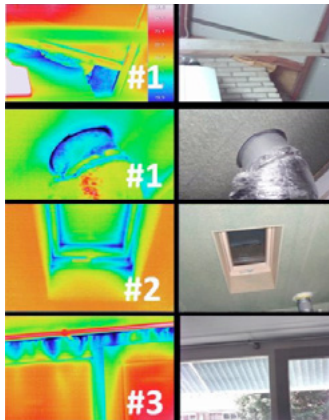


Figure 2: Top 3 of the most common causes of air leaks in 13 highly energy-efficient houses (source: TNO/KoppenVastgoed)

Asking the manufacturer in advance how the ventilation system is to be installed and making sure installation is performed this way prevents noise pollution. For example by using enough space for silencers and by reducing the number of bends.

Projects	% Noise complaint	Measured sound level
Kerkrade	16%	No measurements
Uft	21%	34.1 – 40.4
Amsterdamse buurt	22%	36.1
Montferland	13%	33.5 – 38.7

Table 2: Percentage of residents per project that experiences noise disturbance from the ventilation system in combination with the values of the indicative noise measurements of Transparent Building 2.0 Projects % Noise complaint Measured sound level dB(A)

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With the combination of low temperature heating and natural supply through the outer walls, extra attention should be paid to preventing draught. Some of the products applied are self-regulating grids and new combinations of air supply and heating have been developed.

Extra attention to performance of recirculation cooker hoods is important in order to prevent odour pollution. Residents with recirculation hoods more often complain about lingering odour.

The adjustment and, in the case of a heat recovery system, the balance of the ventilation system is another important aspect. Poorly installed ventilation systems increase energy consumption. Insufficient air-side adjustment, lead to a disturbed balance between supply and exhaust flow in case of heat recovery. As a result of this, the effectiveness of the heat recovery system decreases correlated at the amount of outside air that is extracted instead of inside air.

4 Reduce household energy

Two of the monitored projects scored better on household electricity use. Compared to a similar third project, these projects use significantly less household energy. Both projects actively tried to reduce household energy consumption. The measurement results prove that this effort has paid off.

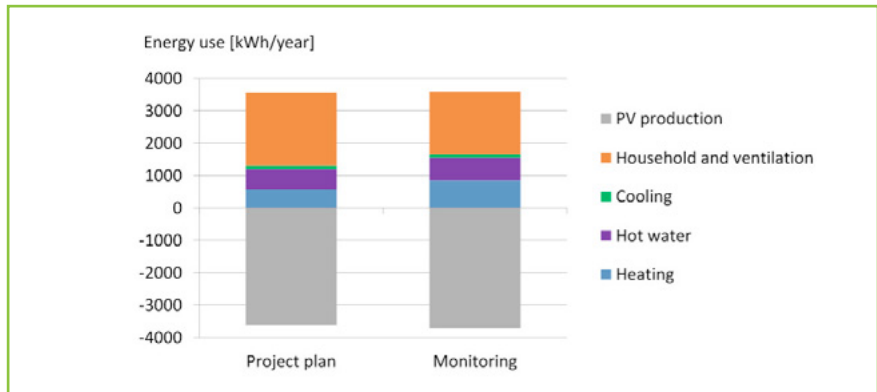


Figure 3: Difference between plan and measured average of 5 dwellings (source: TNO).

This project uses a ground source heatpump and efficient household appliances.

This resulted in a low energy use of "household and ventilation"

4.1 Conscious residents, how does it work?

In one of these projects, there was an explicit goal: make people aware of their positive impact on the reduction of domestic energy consumption. This was done in particular by:

- The issuance of coupons for residents to buy new, energy-efficient household appliances (A++ label)
- The use of stand-by killers (these prevent the stand-by consumption of appliances by completely turning off the appliance when it is in stand-by mode)
- Information toward the occupant for energy reducing behaviour: for example encourage residents to avoid using the dryer

Residents in this project say they are (or have become) relatively energy-conscious. The majority of the respondents indicate that they consciously deal with water and energy and find it important for other people and companies to do so as well. Moreover, in regard to the purchase of new equipment, the majority says that they find economic use of the device more important than the (low) price. Over 40% of the respondents indicate that they apply more conscious energy use since they live in their present (energy-efficient) home.

In the other project, vouchers were made available to buyers for the purchase of energy-efficient LED lighting, a heat pump dryer and at least two A+++ household appliances. Also, 10 stand-by killers and energy-efficient doorbells were made available. The residents thought it was a great initiative. They indicated not to behave differently in their new home than they did in their previous home.

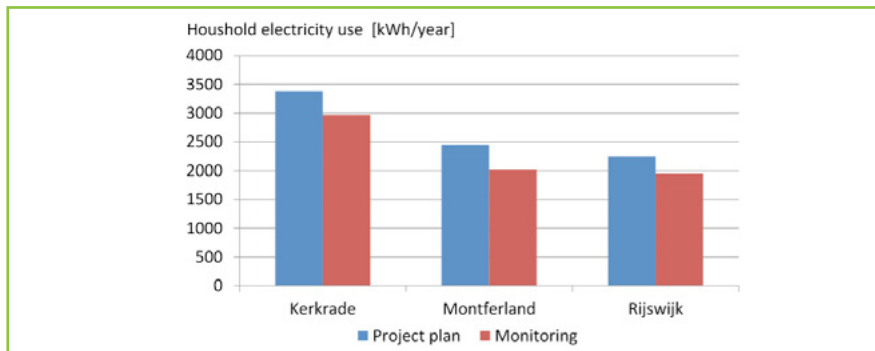


Figure 4: Average household electricity use of three projects (source: TNO)

The residents in this project also indicate that they find the comfort of their home (comfortable temperature and plenty of hot water) more important than whether or not obtaining the NetZero Energy goals. Four out of five dwellings was net producing but one house with a high setpoint for space heating wasn't NetZero energy.

5 Summer comfort

In homes with very good insulation, the risk exists that it gets too hot inside. Residents quite often indicate that they do not find the temperature in their homes pleasant during the summer. In this chapter, we take an in-depth look into the ins and outs of summer-comfort. We do this with practical examples from three projects.

5.1 Passive cooling versus active cooling

In a well-insulated house the heat demand decreases, but the cooling demand does not.



Figure 5: Kerkrade, where passive cooling measures were applied in the shape of an overhang and night ventilation grid (=burglar-free outlet provision) on the ground floor

According to the NEN 7120 the Dutch standard for Energy performance of buildings - Determination method, there is a penalty for cooling. This is the amount of energy that an air-conditioning would need. This is known as the so-called cooling penalty. Better insulation leads to a lower heat demand, but at the same time can lead to a higher cooling penalty.

Table 3:
Percentage residents
per project that finds
their home too hot in summer

Project name	'too hot in summer'
Kerkrade	34%
Amsterdamse buurt	44%
Montferland	25%

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In one of the projects (project Kerkrade), night ventilation and an overhang were applied; 95% of residents experience improved temperatures since the renovation. It should be noted that this is in comparison with a highly dated property. Moreover, 34% of the residents finds the house too hot in the summer after renovation. In the summer, the temperature exceeding in the bedroom is actually very high.

Figure 6 shows the percentage of homes with more than 100 hours of temperature exceeding and the average number of hours of temperature exceeding in Kerkrade. A temperature of 26,5 °C is used here as temperature limit.

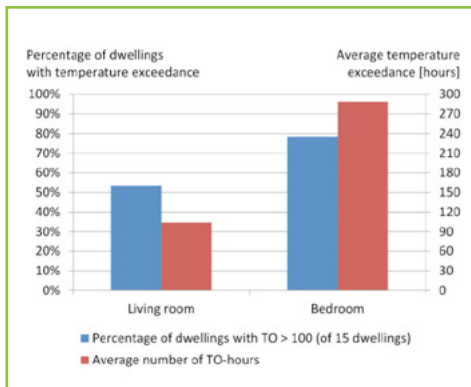


Figure 6: Thermal comfort measured in one of the projects expressed in temperature exceeding (TO, blue) and average number of exceeding hours (red) (source: TNO)

Another example of preventing overheating is found in project Montferland, where active cooling with an air heat pump is used to cool the ground floor. In comparison with other projects, residents are more satisfied. 25% find it too hot in the summer. In addition, the isolation degree is lower than in project Kerkrade.

6. NetZero energy

From the first results of the monitoring in Energiesprong projects, we can conclude that NetZero Energy is actually possible. In the NetZero Energy projects, solar panels (PV) and HE ventilation were used in combination with a well-insulated and airtight outer layer (RC=4.1 sq.m K/W). In this project, a lot of attention was paid to residents' information, monitoring/measuring and construction quality. The results after one year are positive. On average, the monitoring results of the properties show that the homes can be designated as NetZero Energy after the first year. To settle differences in the outdoor climate, it will be conclusively determined five years after completion whether the energy consumption meets the energy use warranty.

The differences in net energy consumption between the properties are partially explained by the thermostat settings, as shown in Figure 7. In addition to this, the monitoring demonstrates that there are considerable differences in household electricity use. Besides consumer behaviour, these differences could also have to do with the composition of households, window use and the degree of presence of the residents.

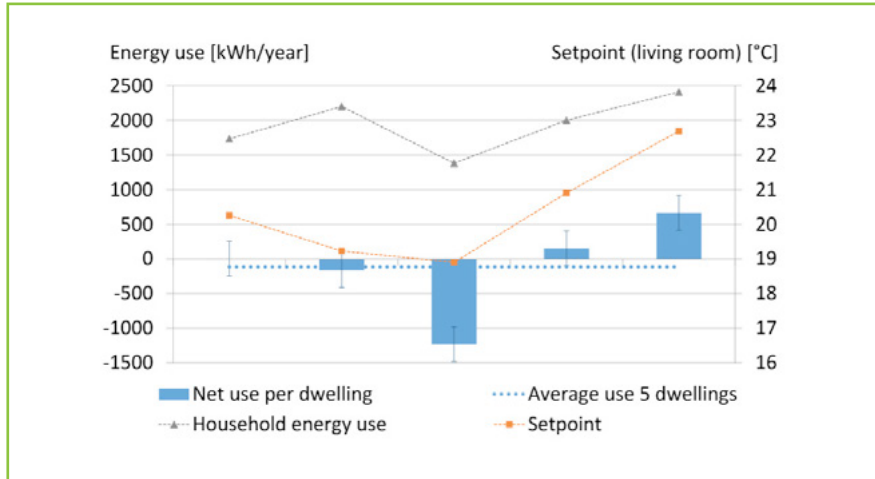


Figure 7: Energy consumption and thermostat setting per property (source: TNO)

Note: The Blue bar chart shows the net annual energy consumption (use - generation) per property as shown on the left axis. The blue dotted line is the average net use of the 5 properties. The grey line shows the household energy consumption per dwelling on the left axis. The orange line is the setting of the thermostat of the properties as indicated on the right axis. Higher values for the thermostat setting and the household use show a higher net energy consumption.

If we analyze several projects which were monitored in the Energy leap program there were a significant number of building mistakes. Airtightness was not as good as promised in several cases, and in most cases the same mistakes were made, for example windows, doors, window and door frames and chimneys. Information, training and quality control is therefore an important aspect also in these very energy efficient dwellings.

Another quick win in saving on energy use is to stimulate the use of energy efficient appliances. In two project this shows as a successful way of being less depended on sustainable production and balancing with the grid.

TITLE
Results from first
"NetZero Energy"
projects in
the Netherlands

AUTHORS
Ing. N.C. Sijpheer

Ir. W.A. Borsboom
Dr. I.J. Opstelten

ORGANIZATION
Platform31
The Hague, the Netherlands
TNO, Delft, the Netherlands
Hogeschool van Utrecht
Utrecht, the Netherlands

MAIL ADDRESS
niels.sijpheer@energygo.nl
tel. +31 6 10444798
wouter.borsboom@tno.nl
ivo@piafwonen.nl

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NETZERO HOUSING RENOVATION

From a technical point of view the refurbishment and restoration of Dutch houses to NetZero energy is a matter of integration of technology. However, despite the clear definition of NetZero renovation, there are no clear examples of how the technical concept of NetZero should be constructed, nor of a concept to make a sound business case of building costs for less than € 45,000. What is known are the fail factors that prevent upscaling. The research question is twofold:

- 1. How do specifications for the elevation in renovation relate to the technical integration of components necessary to achieve NetZero energy use and what fail factors occur in Dutch building practice in pilots?*
- 2. How must the process of design and construction be organized to make NetZero renovation in Dutch context possible for the total sum of € 45,000 investment costs?*

A qualitative research explores arguments for technical failures in design and lack of integration during construction. From this research fail factors are found, that can be related to the high costs in Dutch pilot projects for NetZero renovation. It seems that new integrated design approaches are needed, where faster construction on the site and shorter time to delivery are crucial to cut costs below € 45,000. Saving time puts pressure on the process of demolition and construction at the building site. Comparing shows that putting time pressure on a NetZero renovation projects itself causes reduction in investment costs. The paper concludes with arguments why approaches in integrating design and construction have to shift towards industrializing in production, automation in BIM and towards maximum assembly at the building site.

1 Introduction to Dutch NetZero renovation

One of the first houses to be renovated to NetZero was in the old city center of Delft. It was part of an extensive research on criteria for a successful tactical organizational method for municipalities to speed up the process of innovation (Ravesloot 2005). The technology used to achieve NetZero level was complicated,

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the costs of the renovation were high. After that first case in 1998, several other cases were constructed. According to Dutch policymakers the number of houses to be renovated towards NetZero is around 4,5 million (BZK 2013, Lambregtse 2015). The goal for rented houses, owned by housing corporations, is to make a process that is Zero-10-0. This means that the costs can reach a maximum of approximately € 45,000 per house (Energiesprong 2015):

Zero : A guaranteed NetZero renovation

10 : Construction time is less then ten days

0 : The costs for NetZero renovation are neutral for inhabitants and tenants

The total of costs, interest and repayment on interest are lower compared to paying the energy bill for thirty years. In that case the monthly costs for interest and for repayment on the rate are below the former costs for energy use in the household before the NetZero renovation (Energiesprong 2015). In a Dutch NetZero house the incoming and outgoing energies (heating, cooling, ventilation and warm water, as well as electricity for appliances and installations) are zero on yearly basis, under standardized climate conditions as are agreed on in the Netherlands and in normal average use, as is described in the Dutch norms. Eventually the inhabitants of the NetZero house will not have to pay for energy use, unless their use of energy exceeds the average that was calculated for their type of house. The research focusses on the elevation of the houses, because the interior of the house can not be altered. The renovation is executed during a short period, so that tenants only have to leave the house for a couple of days.

1.1 NetZero in Dutch Building Practice

Seen in the light of national policies for NetZero housing, it means that 300,000 houses a year have to be renovated to NetZero. At this moment in time, 2016, the speed of NetZero renovation is too low. The costs are too high. The costs should be lowered under € 45,000 according to the national policy makers (Lambregtse 2015). Private owners and housing associations should be aware of the technical and organizational challenges in making NetZero renovations affordable. The threshold of € 45,000 will make the Zero-10-0 approach economically feasible. The technical solutions to make this possible are not found yet.

1.2 Technical and economical challenges

The challenge for parties involved in NetZero renovation is to lower the price and therefore make upscaling possible. This can possibly be done by a better technical

integration of building and installation parts as well as a combination of better technical integration with new organizations and financing models. The two research questions focus on two aspects of that integration: the technical specifications the elevation has to perform and the organization process that will make it possible to renovation to NetZero for only € 45,000.

2 Research methodology

The main problem is to make a technical solution for the NetZero renovation that costs less than € 45,000. In fact the problem is split in two. First, there is a technical challenge to make a more integrated design for NetZero renovation fitting as many types of dwelling as possible (for owning and renting). Second, the costs, calculated in the classical model of owner and tenant, must be lower than € 45,000 in order to keep the rent acceptable for social housing. At costs of € 45,000 private owners also might be able to decide to renovate their houses towards NetZero. The research question would be how to find technical and organizational fail factors in current design and construction processes for NetZero renovation.

2.1 Design research on NetZero envelope technology

The first part of the research was aimed at looking for technical solutions that would fit two criteria:

How would a solution respond to known fail factors for NetZero renovation during design and construction and how can the design process be optimized to lower costs and match with known factors for increasing costs?

The first variable to be measured is the amount and quality of arguments for and against technical improvements of the envelope that are necessary to renovate towards NetZero energy balance. The goal is to develop an online survey that can evaluate current NetZero processes in Dutch housing renovation.

Each question in the survey has to correspond with an indicator, representing one aspect of measuring if the technical improvements of the envelope would answer to technical specifications of NetZero renovation. The results can be used to analyze individual case studies and to compare individual cases. In this survey also indicators on how to manage costs are put into questions to explore to what extend the technical solutions are integrated with cost arguments.

2.2 Case studies NetZero renovation processes

The second part of the research was aimed at qualitative comparison of case studies of existing NetZero renovation on costs and time during construction. Five interviews were held with professionals currently involved in Dutch NetZero pilot projects.

The results from the interviews were used to compare five pilot projects. From this comparison an overview of best practices for the NetZero renovation processes has been retrieved. Both parts of the research, technical and organizational, will give an insight in the fail factors in current Dutch NetZero renovations. From there recommendations can be given for improvements in future NetZero renovations.

3 Data retrieving

Indicators to measure the variable, to what extend do the specifications of the elevation in Dutch NetZero renovation comply, are found in literature (Ravesloot 2016), by studying cases from Dutch building practice and from interviews with Dutch experts on NetZero renovation. Especially technical indicators, as are used in energy use calculations, are suitable as indicator. As is practice in Dutch energy calculations, the influence of occupants and of weather are standardized. An extra set of indicators was found in literature and from five interviews with professionals in Dutch renovation, from perspectives like indoor air quality, comfort, safety and maintenance.

3.1 Indicators for technical fail factors NetZero renovation

The indicators used in the survey were: cutting in costs, decrease in energy use combined with production of renewable energy, shorten the time for construction, increase in flexibility during construction, decrease in nuisance for the inhabitants, strong reduction in future maintenance activities and costs, improvement on the esthetics of the facade. Every individual indicator is also measured in terms of costs compared to total costs of the NetZero renovation. The costs are split in materials, work, transport to and from the building site. During execution of the research six Dutch NetZero renovations had just been delivered or were about to be delivered. As many as possible professionals involved in the management of these projects were asked to answer the questions in the survey. From internet and public project information, information was retrieved, which was compared to the answers in the survey. The response to the survey was low, as expected. The answers are comparable to public information from literature. A qualitative analysis shows what commonly is done to make a technical solution in NetZero renovation.

- The first solution is about the choice to demolish the existing envelope or to keep it and improve its quality
- The second solution is to choose the amount of insulation for the roof, facades and floors, as for the window panes
- The third solution is the materialization of the new envelope finish

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- The fourth solution is about how to adjust the door and window frames as part of the facades
- The fifth solution is about how to envelope in its new materialization would fit to the foundation
- The sixth solution is about fitting the individual adjacent houses to each other
- The seventh solution is about how to fit the altered envelope to the roof, that might be altered as well

Note that in all these solutions complications can occur because elements of the new energy system can and should be integrated. This is considered to be integral part of the solution.

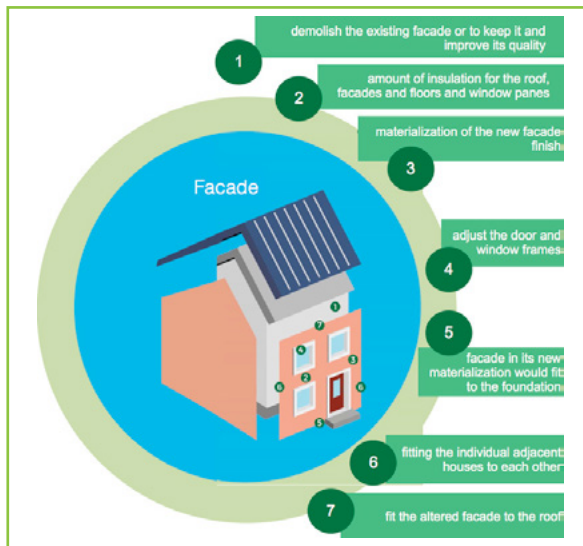


Figure 1: The seven qualitative results coming from the survey according to Agricola (Agricola 2015)

The most commonly chosen solution for insulating the cavity wall is to demolish the outer masonry wall and to replace it with insulation and a finishing outside cladding of some kind. The latest projects however just left the cavity wall and screw new envelope elements on to the existing wall, to gain time. Responds in the survey confirm this:

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- The insulation fixed to walls, roofs and floors is mostly prefabricated in elements and components of many kinds. The variation in the projects is big until 2015. From the survey is learned that high insulation values are common, up to Rc 8,0 M2K/W. Also it became clear that airtightness is an important issue for builders
- The finishing of the outside wall is also different in most projects. Some builders stick to the same finishing, others seem to be experimenting for the right solution. Where in the first projects the edges of the components are to be finished at the building site, it is visible in the later projects that the finishing is part of the connection between components and elements. The survey shows that NetZero concepts for the envelope are based on as many technical solutions with different looks as possible
- In all Dutch NetZero projects window and door frames are prefabricated and part of the elements and components. No further development appears to be necessary. From the survey is learned that windows are made of plastic or wood
- In the first projects the new envelope elements were mounted on the foundation, which required digging of soil. In later projects the digging was avoided by mounting the elements to the facade. This is confirmed by remarks at the end of the survey
- The differences in finishing the joint between two houses is based on single NetZero renovation or multiple NetZero renovations. In the first case the joint to the adjacent house that was not renovated, had to be finished by hand. In the second case the joint is an integrated part of the elements to fit by a small seam, that could also compensate for intolerances in dimensions because of temperature influences. From the survey it shows that the right solutions haven't been found yet. Experiments on this matter have to be continued during the years after 2015
- The joint between new envelope and new roof is mostly made by integrating the gutter in one piece that was prefabricated as well. The survey here also shows that airtightness and aesthetics and a lot of variation to choose from, are important. This detail also needs more development

The final argument to choose for a specific technical solution in NetZero renovation, as was found in literature and in expert interviews, is related tot process factors (in order of importance) (Agricola 2015):

- Decreasing costs
- Decreasing fossil energy losses and increasing renewable energy
- Reducing the time for construction
- Making the process of construction more flexible
- Reducing nuisance for inhabitants and neighbors
- Minimize future maintenance (in effort and costs)
- Improve the aesthetics of the elevation

The results from the literature, survey and interviews do not give a reliable outcome, since the number of case studies is small and the number of respondents to the survey as well as the number of interviews are too low. Qualitatively seen the outcome is rather clear in its conclusion. The experimenting focusses clearly on the seven criteria for specific technical solutions. The next step is to compare case studies on the organizational aspects and in finding resemblances and differences.

3.2 Criteria for case studies NetZero renovation processes

Five different recently delivered Dutch NetZero housing renovations were compared from five different perspectives in the design and construction process (Beamon 1999). The goal is to find the choices that have to be made and actually are being made to renovate five projects towards NetZero. From these choices critical success factors were retrieved. These factors were compared to the results from the first part of the research, the technical optimization in NetZero renovation. From the literature research it was found that NetZero ambitions, NetZero potential and actual energy use after NetZero renovation are not always on the same level. In practice it is not always technically possible to renovate every house into NetZero energy use. First, ambitions focus on average housing types with a theoretical energy use. Practice has to deal with exceptions from the average with a spread in energy use from the average. Second, the energy calculation focussing on the real case, taking exception from the average into account, can not compensate for the influence of the climate conditions and the influence of behavior of the inhabitant of the NetZero house. This is a known fail factor that is not further addressed in this research.

The case studies were compared from the perspective of organization process

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Step in the process	Description
Program	The conditions of the national policy (Energiesprong 2015) and the client
Scanning	The scanning of measures and state of technique
Design	The designing of the NetZero renovation
Procurement	The procurement and contracting of goods and services
Prefabrication	Production of building components in factories
Transport	Delivery of building components at the building site
Demolishing	Demolishing and separation of existing building components
Construction	Production, delivery and mounting of the construction parts
Monitoring	The control and monitoring on the energy performance NetZero

Table Case study comparison of five case studies NetZero renovation in 2015.

The table below shows five pilot case studies for NetZero renovation executed in 2015.

Results analysis	Dutch NetZero	casestudies 2015			
Time related [days]	Haarlem	Nieuw Buinen	Stadskanaal	Den Burg Concept 1	Den Burg Concept 2
Development	50	25	25	20	16
Prefabrication	in situ	10	7	7	in situ
Site preparation	5	2	2	5	5
Demolishment	7	1	1	3	3
Construction	30	2	3	4	12
Houses	30-37	2-3	3-4	4-7	12-15
Total time process [weeks]	18,5	8	7,5	8	7,5
Costs related [%]	Haarlem	Nieuw Buinen	Stadskanaal	Den Burg Concept 1	Den Burg Concept 2
Development	11%	5%	5%	4%	3%
Prefabrication	0%	56%	50%	41%	0%
Demolishment	10%	3%	5%	5%	6%
Construction	79%	36%	40%	50%	91%
Total costs [Euro]	€ 96.000,00	€ 66.000,00	€ 79.000,00	€ 100.000,00	€ 80.000,00
Percentage of total costs related to maximum of 45.000 Euro [%]	213%	147%	176%	222%	178%

Figure 2: The table shows five pilot case studies for NetZero renovation executed in 2015

In these case studies houses built from 1950 to 1980 were considered. The inhabitants do not have an energy bill anymore, provided the use is below average in mean annual climate conditions. The costs for the renovation are not higher than € 45,000 including taxes, according to Dutch policies. The table shows specifications of the

process in terms of time, expressed in days and in terms of costs, expressed in a percentage of the total cost of the projects in Euro. It shows clearly that the costs are lower when time for construction is shorter.

By comparison of five case studies on the processes of NetZero renovations some significant differences in approach become visible (Energiesprong 2015). Assuming that the programs and conditions are more or less the same in all five case studies. Four out of five case studies use 3D scanning technology to make a drawing of the existing building. One used traditional analogue measuring. In this part of the research was confirmed that the details for NetZero renovation were from a standard set of solutions for this kind of renovation, focussing on the seven solutions mentioned earlier in the paper. Differences are caused by load bearing conditions, aesthetic demands, tolerances in the measures and functional demands from the inhabitants. In all cases the use of materials was tested by consultants in different software programs for thermal performance and comfort. In none of the cases the official norm calculation was used. The procurement of the components was executed via offers from regular partners on price comparison.

For those three cases where components for the NetZero renovation were prefabricated, these components would be stored on the site. In three out of five cases the new envelope and roof were completely prefabricated and had only to be mounted to the existing building after demolition of some parts of the existing building. In three cases the outside cladding of the envelope was demolished. In one case also the roof was demolished. In all cases the existing heating installation was taken out of the existing house. In all cases also the windows were taken out and replaced by new ones. In two cases demolished parts were reused and in all cases separately transported to the recycling company.

The new elevations were made of timber framing or sandwich panels. All cases got photovoltaic panels on the roof and energy saving ventilation systems. The process of the case study in Nieuw Buinen was supported by using BIM software.

4 Discussion and conclusion Dutch NetZero renovation

The research on the technical feasibility of NetZero housing renovation resulted in a survey that covers all known indicators for failure. Unfortunately the questionnaire had too little respondents, so the validity is low. The questionnaire itself however, seems to be fit for this kind of research and for future use, when more professionals are involved in NetZero renovation and more respondents can be expected to be able to answer the questions.

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Similar to the questionnaire the number of case studies for comparison on design and construction process is too small to make reliable conclusions. The research is only exploring the possible method of using indicators to measure technical fail factors in renovation elevations in NetZero pilots. At this stage of development in NetZero renovation it is not feasible to make a better distinction between the investment costs during the construction period for the construction company and the total price for the housing corporation or private owners during exploitation. The accuracy of the costs is not good enough to make a fair comparison. In pilot projects like this, many more costs are made, covered by R&D budgets, than can be calculated in investment or exploitation. In the future, when the cost and time savings are passed on from the contractor/construction company to the owner/client and when these costs are included in the price, the tenant will eventually benefit from the savings by paying the same rent and energy costs for a more comfortabel and affordable house. The method of research to make this comparison seems sound for future use, when more case studies are realized. Increase in case studies will improve reliability.

From the survey on technical specifications of NetZero envelope renovation it is clear that the right indicators are found. However, it is also clear that the survey can not be completed by one official connected to a case study, because not all numbers and specifications are known to the professional involved in the NetZero project. It seems that not one person has a complete overview and knowledge of the facts concerning their NetZero renovation. From the qualitative research it seems to be visible that NetZero renovation projects that have a short design and construction process are also the cheapest. Time seems to be the most important positive factor to achieve more affordable NetZero renovations. The factor time is supported by use of 3D scanning technology, decrease of demolition activities, more prefabrication and use of BIM, as well as making standardized details more flexible to the existing building. Working with long term contract partners also increases time during construction, because communication and collaboration run more smoothly. Figure 2 shows the analysis of five Dutch NetZero renovations from 2015 in process, time related and process, money related. It seems that the shorter the time for construction on the site, the cheaper the renovation (Duindam 2015).

Six qualitative arguments for failure in NetZero renovation:

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1) decrease and delay in cost structure, 2) shortening in process time, 3) standardization and more flexibility in building components, 4) reduction in hinder for inhabitants, 5) better aesthetics combined with 6) minimal future repairs and maintenance, can directly be related to:

Five solutions: 1) less demolition, 2) more prefabrication, 3) more industrialization, 4) more automatization with BIM and possible more robotizing of production and 5) more on-site assembly.

Potentially new approaches in integrating design and construction by shifting the costs through industrializing of production and automation in BIM will make it possible to further shorten time of design and construction process without bothering inhabitants and aesthetics and with support to collaboration of professionals during the process of design and construction (Naim and Barlow 2003).

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BUILDING MONITORING TO DETERMINE OCCUPANCY PATTERNS IN RENOVATION PROJECTS

This paper proposes an approach to monitor buildings that will undergo a renovation process in the Netherlands. The objective is to inform the design process of high energy efficient renovations by identifying energy and indoor conditions requirements of different households for building simulation and energy calculations. Furthermore, the process intends to integrate monitoring data into the design of user-centered building control solutions and interventions for behavioral change. This paper informs on the monitoring for the pre-renovation phase of the renovation process. The results of a pilot study showed a wide variety across case studies on occupancy patterns and comfort preferences. A comparison between the households showed that the characteristics of the residents as well as the employment condition and household composition could/may have an effect on comfort and heating patterns.

1 Introduction

Building research in the last years has shown differences between the actual and expected energy performance of building (Virote & Neves-Silva 2012). Some of these differences have been attributed to the influence that the users have on the building operation (Guerra-Santin and Itard, 2010). Given the large differences on energy requirements and household behaviour, post-occupancy monitoring has been proposed for the pre-renovation evaluation of buildings (Stevenson and Rijal, 2010). The pre-renovation evaluation of buildings could provide more insights into the actual household energy requirements, actual occupancy behaviour, and therefore, the most likely operation of the building. This paper proposes a more occupant centred approach to monitor buildings that will undergo a renovation process. This approach is intended to be part of a 2ndSkin renovation strategy for multi-family social rental properties in the Netherlands.

The 2ndSkin project aims at developing a renovation strategy that integrates a technical solution for all utilities, a high-user involvement during design, renovation

and evaluation, and a zero energy performance. In order to ensure a zero energy performance, the yearly energy produced in the building should be equal to the energy consumed during the same year. To decrease the negative effects that occupancy may have on building performance, a pre-renovation monitoring campaign is planned to inform the renovation process.

The objective of the building monitoring campaign within the 2ndSkin project is twofold: the development of specific occupancy profiles for the renovation project at hand, and the understanding of occupants' needs and lifestyles to inform the design and renovation process. Furthermore, the monitoring evaluation seeks to determine actual heating patterns; and to determine occupancy practices to design interventions for behavioural change and building control in future stages of the project.

This paper introduces the monitoring process to evaluate the building occupancy before the renovation and presents the results of a pilot campaign in which the methodology was tested. That said, it is important to add that the studied buildings are not part of a renovation project.

2 Data collection and data analysis

This research seeks to determine household occupancy practices and the effect of comfort and personal attitudes on them. Do users change thermostat setting according to schedules or comfort? Are users able to achieve a comfortable indoor environment? What is the temperature that users define as comfortable? Therefore a mixed-methods methodology has been applied to integrate monitoring of both subjective data on thermal comfort and comfort related practices, and objective data on indoor climate. The mixed-methods methodology offers a strategy for integrating qualitative and quantitative methods to investigate complex phenomena.

The building monitoring process consisted of three types of in-situ and long-term data collection techniques:

- Monitoring of the indoor parameters and contextual data
- Collection of subjective data on comfort and related practices from the occupants
- Describing the ecosystem of energy related practices by walking through the dwellings with the occupants

A paper questionnaire was implemented at the beginning of the monitoring process with the purpose of obtaining contextual information of the household (<http://suslab.eu/>).

2.1 Quantitative data collection

An overview of the methods of data collection and their application can be seen on Figure 1.

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The SusLab Integrated Toolkit and methodology based on mixed methods have been used in this study. The SusLab Toolkit consists of a local network based on Zigbee technology with a HTTP protocol to collect sensor-based data automatically as well as personal data by means of self-reports. Sensors were integrated in a handsome box (SB) to collect indoor climate data (temperature, relative humidity, CO2 level) as well as contextual data such as sound, light and movement. To collect personal information about thermal comfort, the so-called Comfort Dial (CD) was used. Thermal comfort data was collected on a seven-level scale from cold to very warm.



Figure 1: Data collection methods
(SB=sensor box, CD=comfort dial)

Internal temperatures are often used to determine the use of the heating systems in homes. However, several authors have concluded that in some cases, indoor temperatures do not indicate the actual use of the heating system, nor the preferences of the occupants (Kane et al 2015). Monitoring the temperature of room radiators was therefore used to further investigate the use of the heating system. The main factors investigated were the thermostat setting (in Centigrade degrees), the number of heating periods, and the use of radiators. The thermostat setting was defined as the average temperature in the living room in weekdays and weekends during the monitoring campaign (heating period January-March 2014). The difference on temperature between the radiator and the indoor temperature of each space indicated whether the radiator was open, semi-open or closed.

2.2 Qualitative data collection

As part of the mixed-method approach, the integration of the data was done visually per room and per dwelling. Graphs were created to show the residents the indoor conditions of the dwellings in relation to the outdoor temperature. After this preliminary analysis, the residents of the dwellings were interviewed to confirm or

give further information on the assumptions made based on the analysis of the data. During the interviews, the residents were asked for a walkthrough of their homes providing with descriptions and re-enactments on the way they usually control their indoor environment and on their daily practices related to energy consumption. The topics investigated were the use of windows for ventilate, the use of the heating system, and presence at home.

	Dwelling CP37	Dwelling CP38	Dwelling CP39
Household size (family size)	3	2	3
Ages	54, 46, 19	53, 15	54, 47, 15
Occupation	Employed Unemployed Student	Employed Student	Employed Unemployed Student
Type tenure	Social	Social	Social
Type dwelling	Semi-detached	Semi-detached	Church conversion
Last renovation	1984, Glazing, floor insulation	Unknown	1990, 2007, Double glazing, floor insulation
Features	Double glazing, central heating, floor insulation	Double glazing, central heating, Label B	Glazing, floor insulation, central heating Label E
Construction year	Pre-war	Pre-war	Pre-war

Table 1: Households and dwellings characteristics in Rotterdam monitoring campaign

3 Results

Three dwellings were monitored in a neighbourhood in Rotterdam as a part of a winter monitoring campaign (Figure 2). Table 1 shows the main characteristics of the households and the dwellings. Following sections show the results of the analysis.

3.1 Use of heating system and thermal comfort

Figure 3 shows percentage of time in which the indoor temperature in the three dwellings is outside of the required ranges according to the ASHRAE and ISO EN 7730 standards. Dwelling CP37 is almost all the time outside of the recommended temperature ranges; the living room shows the smallest percentage of time with discomfort, which is nearly 70%. CP38 shows that the living room is within comfortable ranges more than 60% of the time, followed by almost 50% of the dining room. The bedrooms in this dwelling are between 70 to 80% of the time outside of the comfortable ranges. CP39 seems to be the most thermally comfortable house with the living room showing 40% of the time within comfort ranges and with the bedrooms showing between 80 and 70% of time within comfort ranges.

Two occupants in each dwelling were asked to report on their thermal comfort level during two separate weeks in the monitoring period. The occupants were asked to only report their comfort level when they were in the living room. Figure 3

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shows the average comfort votes given for each of the houses by the two selected occupants. The highest rating is in dwelling CP37 (5 = Slightly warm), followed by CP39 (4=Neutral) and CP38 (3= slightly cold). This is in contrast with the indoor temperatures which for CP37 are the coldest; while in CP38, the temperature tends to be above the 25 °C threshold (i.e. too warm). These results reflect the subjective differences on occupants’ temperature preferences. Table 2 shows the correlations between comfort votes and indoor temperature. A correlation was only found on dwelling CP39.



Figure 2: Rotterdam case studies

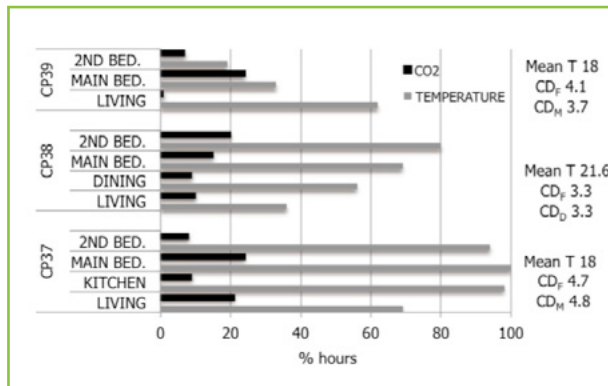


Figure 3: Percentage of hours outside of prescribed ranges according to ASHRAE standards in each room, Mean Temperature (MeanT) and Mean comfort vote (CD) per person, per dwelling

		CP37		CP38		CP39	
		Father	Mother	Father	Daughter	Father	Mother
Temperature	Pearson	0.13	0.05	0.22	0.35	.67**	.64**
Sample size	N	40	52	17	19	43	46

Table 2: Correlation between comfort votes and indoor temperature in living room per dwelling and adult participant

3.2 Occupants motivations on the use of heating system

Figure 4, Figure 5 and Figure 6 summarise the temperature, use of radiators, CO2 concentration levels and presence in the living room for each of the dwellings (except presence in CP39). The responds of the people regarding their usual routines is visualized in the figures. In the figures, we can observe the number of heating periods per day and their relation to presence at home.

In CP37 (Figure 4), the first period is variable since the man is sometimes at home. In this period, during the morning and early afternoon, the thermostat is set to 18 °C. The second period corresponds to the time when all members of the households are home and the thermostat is set higher. It is important to say that the occupants reported to have different thermal comfort preferences: the mother usually feels cold sooner than the father. The strategy followed by the household is to add layers of clothing before turning up the thermostat. In addition, the occupants reported that the mother does not turn on the heating when she wakes up and gets ready to work because she is only there for a short period of time. In this dwelling, we can see that the use of the heating overlaps with presence of people (see lines PRESENCE and Radiators) except in the late evening, when the likelihood of the radiators being on decreases. The occupants report to turn off the heating system one hour before going to sleep.

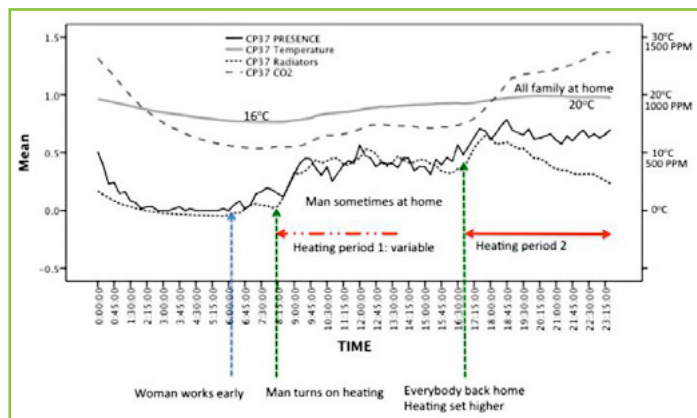


Figure 4: Summary of indoor conditions and building operation in CP37

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In CP38 (Figure 5), two heating periods can be seen, one in the morning, and one in the evening, which also clearly correspond to the periods of presence in the dwelling (see lines PRESENCE and Radiators). However, in this dwelling it can be seen that the heating system is turned on before the occupants wake up, since the system is programmed to be on 21 °C in the morning, and the setback of the thermostat is not very low (19 °C).

Two heating periods are also seen in the dwelling CP39 (Figure 6). A comparison with presence is not possible given either a faulty sensor or the sensor recording the presence of the cat. However, the heating periods slightly correspond to the CO₂ levels measured. In this house, it can also be observed that the heating system turns on during the night to achieve the required temperature in the morning. The Figures also show that in CP37 and CP39, when nobody is home, the thermostat was setback down to 16 °C. In CP38 the setback was much higher (19 °C). The patterns followed by households in CP37 and CP39, as well as their indoor preferences, are quite similar; they also share the fact that only one adult is fully employed. In dwelling CP38, a very different pattern can be seen, since there is only one adult in the household, and he works full-time. However, dwelling CP38 is much warmer than the other dwellings.

The attitudes of the households concerning the environment can be causing some of the differences in indoor environment within the dwellings. The residents of CP37, which is the coolest house, regard the environment as more important than energy costs or comfort. The low setting temperatures might be related to this issue, but the residents also prefer a fresh environment in their bedroom. This household also ventilates very often. The residents of CP38 regard their own comfort as more important than the environment or costs. This dwelling is the warmest of all monitored dwellings. However, the father reported to keep vents open in his bedroom to have fresh air during the night. CP39 is the dwelling with an E energy label. The residents reported to have troubles heating the house and regard energy costs and comfort as more important than the environment.

A comparison between the households showed that the employment condition and household composition can have an effect on the comfort and heating patterns. The unemployed and part-time employed residents had a large impact on heating practices, since these residents spent more time at home. It was also clear that the households followed very different (natural) ventilation practices and also had different temperature preferences.

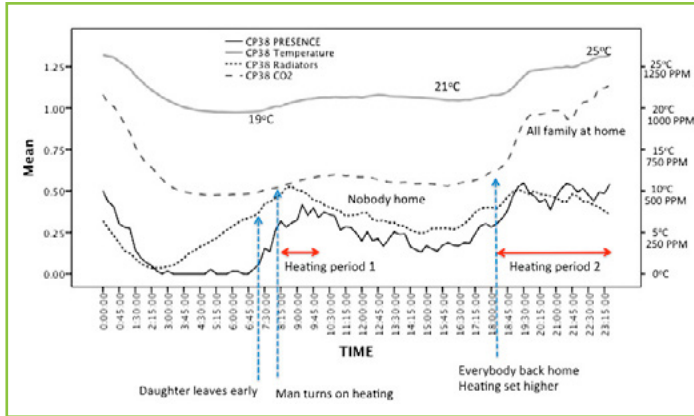


Figure 5: Summary of indoor conditions and building operation in CP38

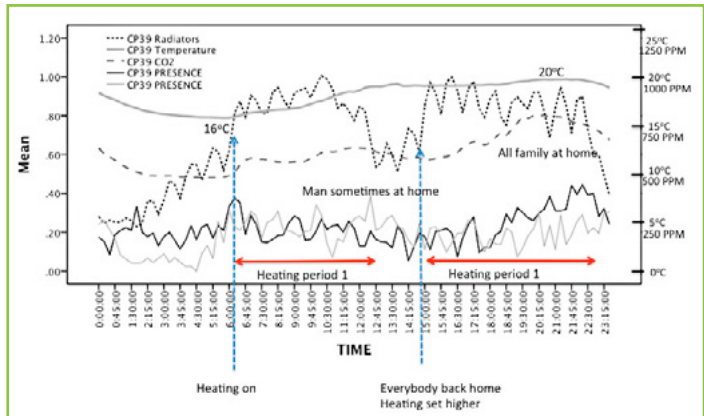


Figure 6: Summary of indoor conditions and building operation in CP39

4 Discussions

This study showed many opportunities related to the research design to obtain accurate and reliable information on occupants' behaviour, however, there were instances in which more information was needed to validate assumptions made based only on the measured data. Objective data on indoor conditions were integrated to subjective data on thermal comfort ratings to determine the comfort of the users. To determine their comfort needs and ability to reach comfort at home, interviews were focused on heating and ventilating practices, and on actions taken to reach thermal comfort.

One of the most important questions was whether the indoor temperatures measured in the dwellings were those desired by the users, since this is related to both the control of the heating system, and the thermal properties of the building. The data allowed making sound assumptions, but only with the feedback from the users we were able to corroborate the information.

5 Conclusions

The results showed that the three analysed case studies have different heating patterns and comfort preferences. A comparison between the households showed that both employment condition and household composition can have an effect on the comfort and heating patterns. However, the qualitative analysis also showed that attitudes of the households concerning the environment can be causing some of the differences in indoor environment within the dwellings.

The results from this study have shown the advantages of the mixed method methodology to obtain detailed and understandable data on heating patterns followed by the residents of the dwellings. The data were integrated and analysed with the objective of obtaining information on occupants' behaviour that could be used on building simulation programs and to inform design. Data integration was on the presence of people at home and on the use of the heating systems.

Furthermore, this study aims at providing a platform to collect, analyse and visualise monitoring data for their integration into design solutions for building control and behavioural change in renovation projects. Future work in this project will aim at designing interventions for behavioural change. In the interventions, we will consider the role of providing effective energy and indoor parameters feedback to increase comfort and decrease energy consumption. Effective feedback would be determined according to the lifestyle, preferences and attitudes of households towards sustainability, costs and comfort.

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TITLE
Building monitoring
to determine
occupancy patterns
in renovation projects

AUTHORS
Dr. Olivia Guerra-Santin
Dr. Sacha Silvester
Dr. Natalia Romero Herrera

ORGANIZATION
Delft University
of Technology
Delft, the Netherlands

MAIL ADDRESS
o.guerrasantin@tudelft.nl
s.silvester@tudelft.nl
n.romero@tudelft.nl

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2NDSKIN, A BUSINESS OPPORTUNITY DRIVEN ZERO-ENERGY APARTMENT REFURBISHMENT APPROACH IN THE NETHERLANDS

The post-war apartments in the Netherlands account for 1/3 of the residential stock. To increase the renovation rate, the product-/service propositions have to change radically. This paper presents the 2ndSkin refurbishment concept – a business opportunity driven research and development projects – that results in zero energy use of dwellings, while minimising construction time and maximizing occupants' acceptance. The project is developing a scalable approach, relying on prefabrication and industrialization, benefitting from economies of scale to drop cost. This is a shift from the traditional, project-based working culture of the construction industry. Furthermore, the paper proposes a business model for similar refurbishment approaches. The model aims at reversing the traditional decision-making process, to facilitate the zero-energy refurbishment introduction to the market..

1 Introduction

Refurbishment is a necessary step to reach the ambitious energy and decarbonisation targets for 2020 and 2050 that require an eventual reduction up to 90% in CO₂ emissions. While new buildings can be constructed with high energy performance levels, the existing stock is predominantly of poor energy performance and consequently in need of renovation work (Atanasiu and Kouloumpi, 2013).

A substantial share of the stock in Europe is older than 50 years with many buildings in use today that are hundreds of years old. More than 40% of our residential buildings have been constructed before the 1960s when energy-building regulations were very limited. In the Netherlands, there are 7.5 million dwellings (CBS, 2015), 1/3 of which is built in the post-war period, between 1945-1975 (Itard and Meijer, 2008). Even though there are various sustainability and other motivations to refurbish

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
2NdSKin, a business opportunity driven zero-energy apartment refurbishment approach in the Netherlands	Ir. Sybren Steensma Dr.-Ing Thaleia Konstantinou Dr.-Ing. Tillmann Klein Dr. Sacha Silvester Dr. Olivia Guerra-Santin	Delft University of Technology Delft, the Netherlands	s.steensma@tudelft.nl t.konstantinou@tudelft.nl t.klein@tudelft.nl s.silvester@tudelft.nl o.guerrasantin@tudelft.nl

existing residential building, prevailing renovation rates, averaged in the EU, are as low as 1% and renovation depths are mostly minor (BPIE, 2011). Both rate and depth of refurbishment must at least double and even triple, compared to the currently observed situation (European Commission, 2013).

The realisation of the potential benefits of refurbishment lays in mass implementation, addressing large numbers of dwellings and achieving major reduction in energy consumption during the building lifecycle. The Energy Agreement for Sustainable Growth (SER, 2013) indicates that 300.000 dwellings have to be renovated in the Netherlands annually. The housing market and the supply chain play a critical role in the renovation process. Currently, due to the high costs pressure, stakeholders work from project to project and financial risks must be minimized. However, to increase the renovation rate, the supply chain has to make a systemic change. Furthermore, there is an increasing demand to upgrade both physical condition and performance of the building, with the minimum disturbance to the interior, so that the occupants do not have to be relocated during the construction. The 2ndSkin refurbishment approach aims at eliminating the energy demand, while minimising construction time and occupants' disturbance.

This paper presents the 2ndSkin refurbishment concept as a business opportunity driven research and development project that results in zero energy use of dwellings. Different stakeholders closely cooperate, to integrate their expertise into an innovative façade and services. The project is developing a scalable approach, relying on prefabrication and industrialization, benefitting from economies of scale to drop cost. To this end, the building stock in the Netherlands is investigated, to understand what the size of the market can be. Subsequently, the barriers in the market are identified through interviews with stakeholders, resulting in suggestions for a shift from the traditional, project-based working culture of the construction industry to an industrialized and integral approach that is required for the supply chain, in order to achieve mass implementation of deep renovation in the residential building stock.

2 The 2ndSKin project scope

The 2ndSKin project brings different stakeholders together to integrate their expertise and objectives into an innovate building technology concept that meets the requirements for zero-energy use of the refurbished dwelling (or block / neighbourhood) and occupants acceptance (Konstantinou et al., 2015). The group of stakeholders include general and façade contractors, Energy Service Companies (ESCO), ventilation and heating services companies etc. Most importantly, the concept will be up-scaled and the process broadly adoptable. The target group for

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
2NdSKin, a business opportunity driven zero-energy apartment refurbishment approach in the Netherlands	Ir. Sybren Steensma Dr.-Ing Thaleia Konstantinou Dr.-Ing. Tillmann Klein Dr. Sacha Silvester Dr. Olivia Guerra-Santin	Delft University of Technology Delft, the Netherlands	s.steensma@tudelft.nl t.konstantinou@tudelft.nl t.klein@tudelft.nl s.silvester@tudelft.nl o.guerrasantin@tudelft.nl

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the present investigation consists of post-war apartment blocks, which account for a large part of the building stock in the Netherlands, in urgent need for renovation. Moreover, next to the technological solution, the project works on tools that can play a role in enabling the parties to elicit citizen participation (Boess, 2015).

2.1 The 2ndSkin refurbishment concept

The 2ndSkin design principle to reach zero-energy dwellings is based on preventing the use of energy, then use sustainable energy sources as widely as possible (renewable) and, finally, if the use of finite (fossil) energy sources is inevitable, they must be used efficiently and compensate with 100% renewable energy (AgentschapNL, 2013). The concept needs to combine the building envelope upgrade, the use of efficient building systems and the generation of energy.

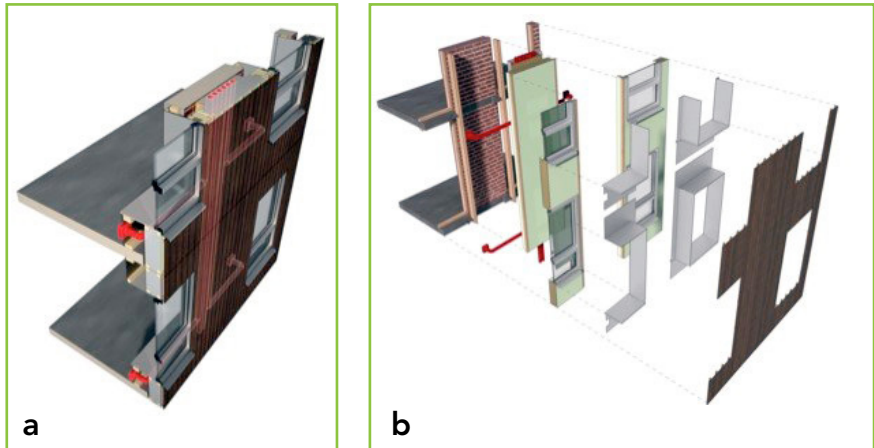


Figure 1: Impression of the 2ndSkin concept. (a) Detailed 3d section, showing the ventilation pipes integration. (b) The sequence of the prefabricated elements installation (from the left to the right)

Firstly the building envelope is insulated with prefabricated sandwich panels, to reduce the energy demand for heating and cooling by increasing the thermal resistance and the airtightness of the envelope components. Moreover, existing windows are replaced. The prefabricated, floor-height, sandwich panels, featuring new windows and integrated services pipes, are attached to the substructure that consists of wooden posts connected to external facet of the existing structures through steel U-profiles. Energy generation is necessary to reach the zero-energy target; thus, PV panels are installed on the roof, while installations to improve ventilation are also integrated in the rooftop. The ventilation pipes are integrated

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in an insulation board, attached to the sandwich panel that covers the opaque part of the existing façade. This panel is installed first and it comes to the building site as one piece, in order to minimise the connections between the pipes. The panels containing the windows are connected to the wooden posts subsequently.

The proposed design results in eliminating the building related energy demand for heating (Konstantinou et al., 2015). Based on the WOO_N2012 (2013) survey the energy consumption for a 2 adult household, which is the average household profile (Guerra Santin et al., 2015), accounts for 198 kWh/m². After the refurbishment, the demand is 72kWh/m², assuming that user behavior regarding the use of electrical appliances, heating patterns and domestic hot water (DHW) will not change. We assume the use of energy efficient appliances, but a conventional shower. For a zero-energy dwelling 43m² of PV panels are needed to cover this demand, while if only the building related energy is considered 10m² of PV panels are needed to compensate for the heating demand.

3 The market potential

Based on the high number of houses built from the 1960s through the 1980s, houses built in this period represent the highest potential for deep renovation, also since a high number of these dwellings still have not gone through a major renovation and are starting to change owner after 30-40 years. (One Stop Shop, 2012). Figure 2 presents an overview of the housing stock, in terms of dwelling numbers per chronological period. The periods are defined by historical and technical circumstances. During the period 1946-1974, which is after the war and until the oil crisis, more than 2 million dwellings were constructed in the Netherlands. As a result, dwellings of the post-war period account for approximately 1/3 of the residential stock. However, these buildings were generally poorly insulated at the time of construction and there is a need for renovation (Itard and Meijer, 2008).

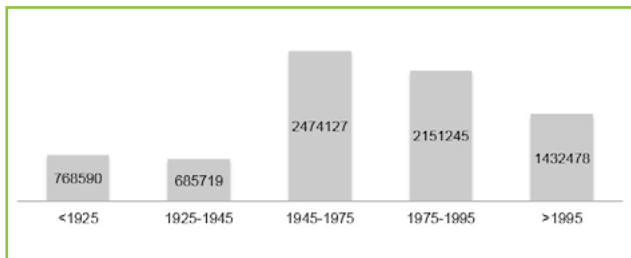


Figure 2: Number of dwellings according to construction year (CBS, 2015)

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Housing associations are an important stakeholder, as 1,3 million of the post-war period dwellings are social housing (Platform31, 2013). There are approximately 400 housing associations in the Netherlands that manage 2,4 million residential properties, constituting 34% of the total housing stock (AEDES, 2013). A large amount of those properties are in need for renovation, as the housing associations have the ambition to achieve energy label C for 80% of their properties and an average label B by 2020 (AEDES, 2012), while currently the average label for the post-war building according to AgentschapNL (2011) is D-E (approx. 350-400 kWh/m²/year primary energy). The energy accord indicates that 300.000 dwellings have to be renovated annually.

	Total residential stock	Post-war residential stock (1946-1974)	Total apartment flats	Post-war apartment flats	Industrialized systems (all dwelling types)
no. dwellings	730,000	260,000	878,000	381,000	450,000
% of the total stock in the NL		36%	12%	5%	6%

Table 1: The Dutch building stock in numbers (source: Platform31, 2013)

4 Supply chain analysis and barriers identification

For the concept design and most importantly the realisation, the supply chain plays a critical role. Proposing a new business model for the construction and delivery of the retrofitting components is part of the project objectives. The first step is to identify the barriers within the supply chain for mass-implementation of refurbishment and zero-energy renovation, in particular.

To this end, the project partners and other stakeholders were individually interviewed about their ambitions and expectations, as well as experiences regarding zero-energy renovation. These interviews had a qualitative perspective and, as such, were semi-structured (Bryman, 2012) around a set of themes such as market opportunity, strengths & weaknesses of the consortium, business development. The interviewees were selected from the refurbishment stakeholders' group, based on their experience and role in the process. In the Netherlands, general contractors (GC's) are involved in almost all projects. They have a major role in facilitating a project and carry responsibilities towards the client. The architect makes general design specifications and the real execution design is left to GC. A huge number of competing products is available on the market. Suppliers try to compete on quality and price relations. In many cases the façade builder gets bypassed and the GC has direct relation to suppliers.

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4.1 Barriers analysis

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One of the biggest barriers for the market entrée and adoption of a concept such as 2ndSKIN, is the scale. Doing innovative renovation projects on a small scale such as 1, 2 or 10 apartments at a time has proven to be very costly. In general, these projects are only feasible if the (local) government subsidizes the project to cover additional investment. Interestingly, this has been done quite a lot in the Netherlands due to a long tradition of subsidy programmes. At the same time, it has been generally recognized that many of the subsidized concepts never make it past the subsidy stage, and fail to gain a large-scale implementation.

However the size of the market is huge (300.000-500.000 apartments to be renovated in the Netherlands, in order to reach energy neutral built environment by 2050) and offers the opportunity to employ large scale, industrial and prefabricated integrated product (and services), taking advantage of the economies of scale such as high volume procurement price reductions, prefabrication, reduction of errors and in general the opportunity to redesign the construction process.

However, to really benefit from these economies of scale also requires a new mindset among the parties involved. A change in perception is needed from a project orientation towards a product-service orientation. This means that the parties involved should look beyond the scope of the specific project at hand, and do their cost-benefit analysis based on the expected market.

Within the traditional project orientation, partners would calculate their price for the given project, and would only actually contract it if it would generate a profit within the scope of that specific project. If the project is the renovation of 6 dwellings, the fee will be calculated for 6 houses. This way, investments in innovation will only happen if they have a full return of investment within the current project. Additionally, economies of scale of e.g. large-scale procurement are never really exploited.

A second barrier in traditional project orientation of the construction industry is that the incentives can be pushing the partners in a wrong, ineffective direction. Because the value chain dissolves after the current project, the partners involved will have make their profit within the scope of that project. Typically, the profit is directly correlated with the amount of work, in terms of hours and materials. So there is always an incentive to maximize that amount of work per job. However, for the development a large-scale concept such as 2ndSkin, the work per job obviously needs to be minimized, not maximized. The next chapter describes how incentives can be better aligned with this purpose.

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4.2 Business model suggestions for the 2ndSkin

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A step-by-step strategy is being developed for the 2ndSKIN concept. To understand these steps, we first define the current situation as step 0. This is the status quo as described earlier where the general contractor is in charge of the project and distributes the work to the subcontractors.

In the first step, the partners would enter into a multi-annual agreement that describes how they will share investments in and revenues from the product development and market introduction of 2ndSKIN. Sharing total project revenues gives the partners the incentive to minimize their work per job, because that would cause an increase of the overall pie that is left to share. At the same time, partners need to make sure that the necessary innovation costs that go into the development will be shared among the partners on a fair, equal basis.

This new way of working together has in fact more similarities to starting a new business together than doing a traditional construction job. So in step 2, the partners' agreement will be formalized into the setup of a new business.

In the third step, a new partner should get involved in the formalized consortium: a financier. It is expected that over the long run, clients such as housing corporations might be interested in additional financial services. A long-term perspective is that façades shall be leased to corporations instead of sold.

5 Conclusion

Given the need to eliminate the energy demand of existing dwellings, this paper presented the 2ndSkin approach, a refurbishment concept that aims at a zero-energy dwelling, with minimum interference with the dwelling interior. This is achieved by upgrading the building envelope with prefabricated façade modules, integrating building services and energy generation.

The concept has the potential for mass implementation, as the market size of the project target building type accounts for approximately 300.000 dwellings. The proposed solution can be applied in a large number of cases. It addresses the different aspects. The objective is not only to find a successful refurbishment strategy for a specific building type, but also to determine the framework within which the proposed solution can be adjusted.

Nevertheless, the current structure of the supply chain poses a barrier to mass implementation. The proposed business model for the 2ndSkin is to create into a

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multi-annual agreement for revenues sharing, giving the partners the incentive to minimize their work per project. Involving a financier can result in a more attractive model for the different parties. The next steps of the research will investigate further the potential and the market adaptations needed for new business of the refurbishment practice and the implementation of the 2ndSkin approach in particular. Moreover, the technologies to be retrofitted and their integration need to be further developed to facilitate the new business model.

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IMPROVING LABOUR PRODUCTIVITY OF FAST RETROFITTING CONCEPTS OF NETZERO ENERGY HOUSING IN THE NETHERLANDS

The authors examined how to improve the total (onsite and offsite) labour productivity of production and assembling of fast retrofitting concepts in the Netherlands. The authors analysed the collected data of two NetZero energy renovations in which the initial proces were quite traditional. In the first case the labour productivity can increase spectacularly by prefabricating the roof. In the second case the providers modernized the processes by working in multi-disciplinary teams. No evidence have been found that working in a multi-disciplinary team can increase the labour productivity but the time for realization did decrease.

1 Introduction

In the Netherlands clients and builders are searching for product systems for fast retrofitting of NetZero housing. Organizations such as social housing associations, contractors, investors, municipalities, etc. who are member of “Stroomversnelling” (rapids) are experimenting with industrialized NetZero retrofitting concepts. Together they have renovated a few dozens of houses built between 1950 and 1980. An important precondition for the renovation is that the households don’t pay more for their housing after the renovation. The rent after the renovation is equal to the rent plus energy costs before the renovation.

Because the retrofitting has to be paid by the savings on the energy bill, investors and providers are searching for new business models. Important aspects to establish a viable business case are the rent (before and after the renovation), the energy costs (before renovation), renovation costs, discount rate, and cost of maintenance and property value (or the estimated selling price at the end of exploitation).

To make the business case attractive for commercial investors, social housing organizations have to look differently to their traditional business. Nowadays social

TITLE	AUTHOR	ORGANIZATION	MAIL ADDRESS
Improving labour productivity of fast retrofitting concepts of NetZero energy housing in the Netherlands	Martin van Dijkhuizen MSc Rogier Laterveer MSc	HU University of Applied Sciences Utrecht, the Netherlands	martin.vandijkhuizen@hu.nl tel. +31 6 38149041 rogier.laterveer@hu.nl

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housing corporations use the so-called 'discounted cash flow method' in which they base the value of the property on the total lifetime. However the market value method (fair value method, open market valuation) is closer to fair property values and therefore gives more reliable input for commercial financing.

On the other hand contractors have to look for methods to lower the costs of renovation. Providers are using lean principles, including process optimization, industrialization and changing the mentality of construction workers to lower the costs (Höök, 2008). Step-by-step contractors change the traditional renovation process into a fast retrofitting concept. Those concepts cost a lot of money and time though. On the other hand the production and assembly of the fast retrofitting concepts save a lot of money and time so that in the end the fast retrofitting concept of NetZero energy housing should become cheaper than renovating the same NetZero energy housing in the traditional way. Additional is the time the renovation takes on site because the customer keeps on living in the house during the renovation.

In this paper the authors give an answer to the question: How to improve the labour productivity of production and assembling fast retrofitting concepts? With this answer and the costs of labour, which is out of the scope of this paper, providers can calculate how much they can save on the total cost of their retrofitting concept. And therefore they can conclude if a fast retrofitting concept can reduce the total costs of a renovation.

First this paper discusses the definition of labour productivity and factors that influence labour productivity. After that the labour productivity of two traditional NetZero renovations will be calculated. The characteristics that influence the labour productivity of the two cases will be discussed. In earlier research on both cases researchers made recommendations on how to improve the traditional renovation to a fast retrofitting concept. Measuring the labour productivity, as mentioned in this paper, wasn't the purpose of the researches. Therefore this paper will discuss those recommendations and will calculate the gain in labour productivity when those recommendations are accepted.

2 Definition and factors that affect labour productivity

2.1 Definition of labour productivity

A review of construction journals by Wen Yi and Albert P. C. Chan concludes that there's no agreement about the precise definition of productivity (Yi & Chan, 2014). The definitions differ in which elements productivity includes and they differ in what is meant by high productivity.

Economists and accountants define productivity as the ratio between total input of resources and total output of product. Resource input includes the elements labour, materials, equipment, and overhead. Output can be measured as the total money value of construction put in place. (Hanna, Taylor, & Sullivan, 2005).

$$Productivity = \frac{\text{input of resources}}{\text{output of product}} = \frac{\text{€x}}{\text{€y}}$$

Equation 1

Construction activities are normally labour-intensive (Song & Abourizk, 2008). That's why in construction project managers and construction professionals often define productivity as a ratio between the two elements: earned work hours and expended work hours, or work hours used. (Hanna, Taylor, & Sullivan, 2005)

$$Productivity\ index = \frac{\text{budgeted work hours}}{\text{actual work hours}} = \frac{x\ \text{hours}}{y\ \text{hours}}$$

Equation 2

Previous industry studies differ in what is meant by high productivity. (Park, Thomas, & Tucker, 2005)

$$Productivity = \frac{\text{output}}{\text{input}}$$

Equation 3

or

$$Productivity = \frac{\text{input}}{\text{output}}$$

Equation 4

The first equation means that a high output of production with a low input of resources results in a high productivity. The second equation means that a high output of production with a low input of resources results in a low productivity. The second form has been widely used and existing in literature over the years in the construction industry (Park, Thomas, & Tucker, 2005). But project managers and construction professionals in the Netherlands are speaking of high productivity when there is a high output of production with a low input of resources. Therefore this research adopt the first equation. This research will examine how to improve labour

TITLE	AUTHOR	ORGANIZATION	MAIL ADDRESS
Improving labour productivity of fast retrofitting concepts of NetZero energy housing in the Netherlands	Martin van Dijkhuizen MSc Rogier Laterveer MSc	HU University of Applied Sciences Utrecht, the Netherlands	martin.vandijkhuizen@hu.nl tel. +31 6 38149041 rogier.laterveer@hu.nl

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productivity. This research compares differences in process between fast retrofitting concepts and traditional NetZero energy renovations. In this comparison the output of both methods is the same: one house, or one part of the house. That's why labour productivity in this research is defined by Equation 5:

$$\text{Labour productivity} = \frac{\text{building parts}}{\text{labour hours}}$$

Equation 5

When observing a traditional renovation a lot of labour will be at the building site. Providers of fast retrofitting concepts use prefab elements and are moving the labour from building site to factories. To make a fair comparison in labour productivity this research defines the offsite labour hours also as labour hours. In this research the definition of labour hours is an (clock)hour spent (by the providers) on a manual worker for the complete renovation. That also means waiting time for instance.

2.2 Factors that affect productivity

There are numerous factors which influence labour productivity. These factors could be classified as (Shehata & El-Gohary, 2011):

- **Industry related factors** such as complexity and repetition of design, codes, laws and regulations, job duration, size of the job and type of job, weather and seasonality, site location
- **Management related factors** such as planning and scheduling, leadership, motivations and communication
- **Labour related factors** such as labour skill, motives and labour availability

Farnad Nasirzadeh and Pouya Nojedehi divided the factors in another way. They depict the affecting factors of labour productivity as lack of working area, skilfulness and project management efficiency as seen in Figure 1. (Nasirzadeh & Nojedehi, 2012). In this figure an arrow with an "+" means: "has a positive influence on..."

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Not every possible factor that affects the labour productivity is within this model. For instance the influence of complexity of design, regulations and availability of labour are not in this model. Nevertheless this model gives a good base to give insight in factors that influence labour productivity.

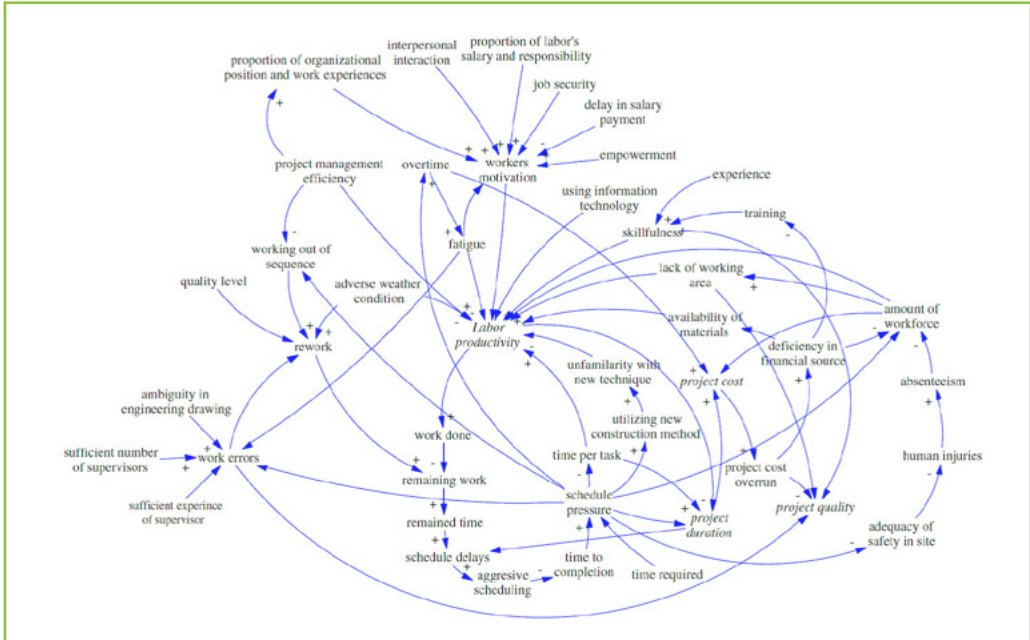


Figure 1: Conceptual model of labour productivity (Nasirzadeh & Nojedei, 2012)

3 Characteristics of two NetZero renovations

This chapter discusses two cases of NetZero renovations. For both cases the authors discuss the characteristics, the labour productivity and the specific factors that affect labour productivity of the two cases.

3.1 Case 1: Tilburg

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Figure 2: NetZero renovation in Tilburg, the Netherlands (Berben, 2015)

Characteristics

The first case is a NetZero renovation in Tilburg. Although the final product was very modern (NetZero), the process of the renovation was traditional. For instance the roof was made traditionally with purlins. The roofing sheets were lifted piece by piece to their final location. The work was very labour intensive. (Berben, 2015)



Figure 3: Roofing sheets were lifted piece by piece (Berben, 2015)

Labour Productivity

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In a research Berben (2015) focused on the realization of the roof. He measured the labour hours needed for demolishing and mounting of the roof. In his calculation he excluded the (pre)fabrication hours of purlins, floors and roofing sheets. Berben estimates that wood work needs 0.17 hour per roof and roofing sheets needs 0.5 per m² roof.

Task	Traditional renovation	Measured or Estimated?
1a	Demolishing roof	7.5
2a	Mounting bearing structure	4.72
3	Mounting roof	13.63
4	Mounting gables	5.28
	Labour hours on site	31.13
	(Pre)fabrication hours wood work	0.17
	(Pre)fabrication hours roofing sheets	33.0
	Total	64.3

Table 1: Measured and estimated labour hours for the roofs of case 1 (Berben, 2015)

The average labour hour per roof was 64.3. So the productivity for case 1 is:

$$Labour\ productivity = \frac{roofs}{labour\ hours} = \frac{1}{64.3} = 0.016$$

Equation 6

Factors that affect Labour Productivity

Berben used the stream analyses of Porras (Porras, 1987) to show the bottlenecks of the realization. The authors found the following factors that influence the labour productivity in case 1:

The authors found the following factors that influence the labour productivity in case 1:

- Adequacy of safety on site
- Lack of working area
- Complexity of design (a lot of dimensioning needed)
- A lot of remaining work (a lot of small parts to be assembled on the building site)
- Construction changes
- Lack of skilfulness

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- Increasing time per task
- Availability of materials
- Schedule delays (subcontractors are too late)
- Work errors

3.2 Case 2: Soesterberg



Figure 2: Case 2 Soesterberg (Mulder, 2016)

Characteristics

In this case the providers renovated 81 houses in several phases from 2014 to 2015. The providers modernized the process by mounting conceptual prefab elements for roof and façade. But on the other hand the process was traditional because it was based on a fragmentation of tasks. The providers improved the process in every phase. Mulder (2016) (supervised and supported by one of the authors) researched the advantages of working in multi-disciplinary teams. She compared the interior finishing of phase 2 where the process was characterized by a fragmentation of tasks with phase 3 and 4 in which the provider took first steps in working with multi-disciplinary teams.



Figure 5: Process partly modernized (Sav, 2014)

Labour Productivity

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Phase 2 was executed from October 2014 to January 2015. All the subcontractors had their own tasks and they completed the tasks for a fixed price. The contractors didn't monitor their labour hours. Mulder interviewed site managers and concluded that the renovations took 132 labour hours per house. But these hours were exclusive the unproductive hours like waiting, walking, pausing. Therefore it is impossible to calculate the labour productivity for the traditional phase 2. The only thing that can be concluded is:

$$\text{Labour productivity (phase 2)} = \frac{\text{houses}}{\text{labour hours}} < \frac{1}{132} = 0.000758 \text{ (exc. prefabrication)}$$

Equation 7

Factors that affect Labour Productivity

The providers didn't monitor the labour hours but monitored the execution time per house. The average execution time per house was 15.9. This was 10.9 days more than planned.

The causes for this delay were:

- Every party has to return several times to the same house
- Parties have to wait for each other when a task is not finished
- Material is not always available
- A lot of personnel in one house
- A lot of exceptions on design (Mulder, 2016)

Translated to factors that influence labour productivity:

- Increased time per task (returning and waiting)
- Availability of materials

- Lack of working area

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- Small repetition of design

4 Improving labour productivity

4.1 Case 1: Tilburg

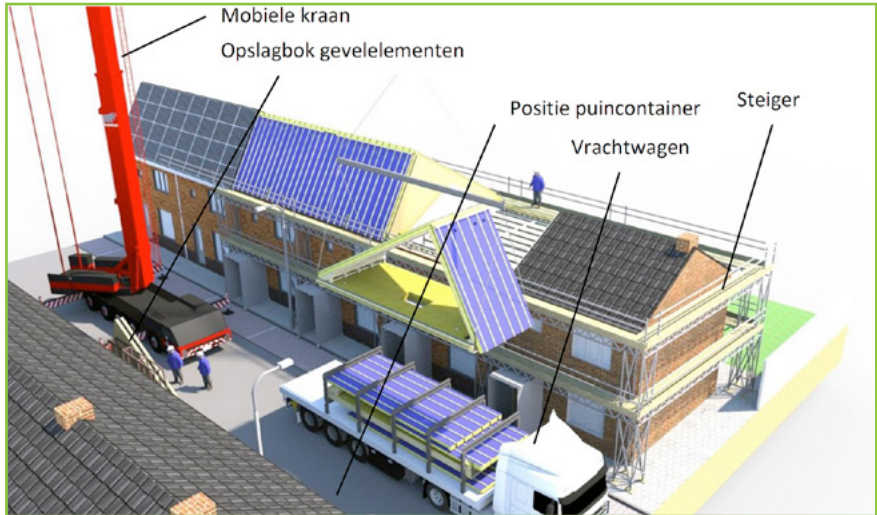


Figure 6: Fast retrofitting concept for roof of case 1

Berben (2016) designed a fast retrofitting concept for building the roof of case 1. By prefabricating the roof he expects that it is possible to act on the bottlenecks as shown in Figure 4. He calculated that mounting the roof in this way can save 10.92 labour hour on site per roof (Table 2).

Task	Traditional renovation	Retrofitting roof concept	
1a	Demolishing roof	7.5	7.5
1b	Preparation prefab roof	0	0.88
2a	Mounting bearing structure	4.72	2.58
2b	Adjustment for prefab roof	0	0.80
3	Mounting roof	13.63	3.26
4	Mounting gables	5.28	2.13
5a	Fitting sheet	0	1.68
5b	Waterproofing	0	1.38
	Labour hours on site	31.13	20.21
	(Pre)fabrication hours wood work	0.17	0
	(Pre)fabrication hours roofing	1.0	0
	Prefabrication hours roof	33	16
	Total	64.30	36.21

Table 2: Comparing labour hours between traditional renovation of roof and fast retrofitting concept in Tilburg, the Netherlands (Berben, 2015)

Berben built a prototype. He estimates that the labour (pre)fabrication hours of the fast retrofitting concept of the roof are 40 when manually made and 16 when made industrial. The labour productivity of the roof can be calculated:

$$\text{Labour productivity} = \frac{\text{roofs}}{\text{labour hours}} = \frac{1}{36.21} = 0.028$$

Equation 8

4.2 Case 2: Soesterberg

To improve the renovation in Soesterberg the different providers tried to work in multidisciplinary teams. Those teams did most of the interior finishing with a high level of independency. In interviews the parties expected several advantages: (Mulder, 2016)

- reduction of disturbance
- increase of workers motivation
- reduction of schedule pressure
- increase of time per task
- reduction of overtime
- reduction of rework
- increase of project quality
- labour responsibility
- reduction project cost and flow

Mulder expected the interior finishing of one house would decrease from 15.9 days (phase 2) to 5 days (phase 3 and 4). Now the providers monitored the time needed for renovating one house. The average execution time was 7.75 days (phase 3) and 10.5 days (phase 4). Although the average time of the renovation decreased, the decrease wasn't as expected. Mulder calculated the labour hours needed for assembling one house. She concluded that the teams worked 1032 hours while renovating 7 houses (phase 3) and 4648 hours while renovating 32 houses (phase 4).

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$$\text{Labour productivity (phase 3)} = \frac{\text{houses}}{\text{labour hours}} = \frac{7}{1032} = 0.00680 \text{ (exc. prefabrication)}$$

Equation 9

$$\text{Labour productivity (phase 4)} = \frac{\text{houses}}{\text{labour hours}} = \frac{32}{4648} = 0.00688 \text{ (exc. prefabrication)}$$

Equation 10

Unfortunately the authors can't conclude if the labour productivity has been increased or decreased in phase 3 and 4 because the labour hours of phase 2 weren't monitored. But the authors found factors that influence labour productivity in interviews Mulder did after she saw an unexpected exceedance of the schedule:

- Lack of appropriate communication
- Lack of project management efficiency
- Lack of experience in working in a multi-disciplinary team
- Lack of training in working in a multi-disciplinary team
- Lack of skilfulness in working in a multi-disciplinary team
- Working out of sequence
- A lot of work errors
- A lot of rework
- Wrong estimation of remaining work
- Availability of materials
- Lack of empowerment
- Lack of labour's responsibility

- Lack of workers' motivation
- Lack of amount of workforce
- Lack of interpersonal interaction

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5 Conclusion

In the table below the authors present the results of the analysis of two cases in one overview.

Case	Traditional renovation		Fast Retrofitting Concept		
	Factors that affect labour productivity	Labour productivity	Concept	Factors that affect labour productivity	Labour productivity
Case 1: Tilburg	Low adequacy of safety on site, Lack of working area, Complexity of design, A lot of remaining work, Construction changes, Lack of skilfulness Increasing time per task, Availability of materials, Schedule delays, Work errors	0.016 roofs per hour	Prefabrication of roofs	Adequacy of safety, Enough working area, Simple design, Little remaining work, Little construction changes, Skilful personnel, Appropriate planned time per task, No schedule delays, No work errors	0.028 roofs per hour
Case 2: Soesterberg	Increased time per task (returning and waiting), Availability of materials, Lack of working area, Small repetition of design	< 0.00758 houses per hour	Multi-disciplinary teams	Lack of appropriate communication, Lack of project management efficiency, Lack of experience in working in a multi-disciplinary team, Lack of training in working in a multi-disciplinary team, Lack of skilfulness in working in a multi-disciplinary team, Working out of sequence, A lot of work errors, A lot of rework, Wrong estimation of remaining work, Availability of materials, Lack of empowerment, Lack of labour's responsibility, Lack of workers motivation, Lack of amount of workforce, Lack of interpersonal interaction	0.00688 houses per hour

Table 3: Overview of results of the two cases

In the first case the labour productivity will increase spectacularly by prefabricating the roofs. This increase can be explained by the fact that the prefabrication will be in an industry hall where the climate and labour circumstances can be controlled. By prefabricating the roofs the builders influence the factors that affect the labour productivity. They influence factors such as the working area, simplicity of design and amount of construction changes.

TITLE	AUTHOR	ORGANIZATION	MAIL ADDRESS
Improving labour productivity of fast retrofitting concepts of NetZero energy housing in the Netherlands	Martin van Dijkhuizen MSc Rogier Laterveer MSc	HU University of Applied Sciences Utrecht, the Netherlands	martin.vandijkhuizen@hu.nl tel. +31 6 38149041 rogier.laterveer@hu.nl

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Mulder monitored the realization of a fast retrofitting concept by multidisciplinary teams. In interviews all the providers expected several advantages, for instance increase of labour productivity. But because the traditional process hasn't been monitored, the authors can't conclude if the labour productivity will increase by working with multi-disciplinary teams.

There is no evidence that working in a multi-disciplinary team in fast retrofitting concepts can increase the labour productivity. But it would be unfair to conclude that working in a multi-disciplinary team will decrease the labour productivity. Working in multi-disciplinary teams is a new concept for the providers of Soesterberg. It is expectable that unexperienced contractors are in a learning curve. Further research has to point out if working in multi-disciplinary teams by experienced teams will increase the labour productivity.

As mentioned in the introduction not only the increase of productivity is of high importance. Also important is the time it takes to renovate on site because the customer keeps on living in the house during the renovation. The authors showed in the analyses that if the companies redesign their products and organize the processes in a sensible way the effect is a reduction of time on site and probably a better acceptance from the customer.

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Improving labour productivity of fast retrofitting concepts of NetZero energy housing in the Netherlands	Martin van Dijkhuizen MSc Rogier Laterveer MSc	HU University of Applied Sciences Utrecht, the Netherlands	martin.vandijkhuizen@hu.nl tel. +31 6 38149041 rogier.laterveer@hu.nl

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THEME 2 GOVERNANCE: LEGISLATION & POLICIES, EUROPEAN CHANCES, STAKEHOLDER INVOLVEMENT AND IMPACT OF LOCAL/NATIONAL AUTHORITIES



Transition in urban sustainability as a global gateway to innovation. The impact of local, national and international authorities could be leading or freezing. This track will prove that there is a genuine interest among professionals working in different areas of the world to share good practice and investigate collaboration opportunities. The focus is on issues such as the impact of local authorities, the European challenges and the influence of stakeholder environments.

- a. Impact of local authorities on the upscaling of E-refurbishment
- b. European chances & national legislation: leading or freezing
- c. Influence of (multi)stakeholder involvement & alignment and acceptance of new technology
- d. Policies to overcome market barriers

FM&BIM: A MULTI-DISCIPLINARY APPROACH OF BUILDING INFORMATION

This paper shows the importance of BIM to strongly increase the quality of the exploitation of buildings, by increasing the quality of the indoor climate, and reducing the energy consumption and the exploitation costs. Opposite to the present situation, facility managers should be the owners of this "exploitation BIM" and have to know which information they must extract from the BIM and how to manage this information.

1 Introduction

Much research has already been done into the perception of comfort and indoor climate by end-users and the corresponding energy usage (Joosstens & Itard 2012). Generally, neither the quality of the indoor environment as perceived by the end-users, nor the energy consumption are found to meet the expectations and design specifications. The indoor climate even turns out to be the biggest source of complaints of all facility services and the energy consumption may be up to 30% higher than expected.

Despite high technology developments in the design and use of HVAC systems, the building-related complaints from building users are still common, especially when energy saving measures are taken as these measures often results in less fresh air flows (see for instance many publications on www.isiaq.org) and the energy consumption of these systems is much higher than one would expect, savings of 30-40% in energy consumption are still possible by automated energy commissioning through energy management systems (Zang et al, 2008, Taal et al, 2015). Even very sustainable buildings show declining energy performances over time, hindering the necessary energy transition towards low energy buildings. Research shows that a poor indoor climate will lead to a reduction of 10% to 15% of the output of the organization (Boerstra, 2010), a decrease of performance of the end users and increase of illness (Boerstra e.a. 2006). Our own research (Joosstens & Itard 2012) shows that a large part of the problems comes from the poor cooperation between facility managers and people from technical maintenance. Based on these results, further research was undertaken by taking more than 40 interviews in different organisations and

doing desk research. The aim of the research is to determine which information is relevant to facility managers, how to use this information, what developments are taking place in information management and what possibilities there are for a more effective use of these resources. The present paper highlights the results of this research with focus on existing buildings.

2 Information systems for Building Management

There are several information systems that can be used to steer effectively and efficiently on both the experienced and the technical quality of the indoor climate, on the energy consumption, on the efficiency of the maintenance process and on the use of the building.

2.1 Building Management systems (BMS)

A building management system is a computer based control system that is used by managers of a building with the purpose of creating an optimal working environment and the purpose of early stage detection and identification of errors in the systems, reporting unusual patterns in energy use and offering an effective approach to achieve energy targets (Australian Government 2010). A BMS consists of two main parts: the automation of processes and the provision of information.

Information on energy consumption is a component that can be included in a BMS if wanted.

This information can contribute to the preparation and management of performance contracts (Verbeek 2015).

2.2 Building energy management systems (BEMS)

Energy management is crucial to achieve zero-energy buildings in practice. Through continuous monitoring, with the help of these systems energy savings between 10 and 40% are possible (Ahmed et al, 2010). The aim of energy management is to carry out on a structural and economically responsible way, organizational, technical and behavioral measures in order to minimize the use of energy, including the energy for the production and use of raw materials and consumables (Agentschap NL 2010 & 2011).

It is expected that an integrated approach with regard to the purchase of energy, the functioning of the systems and the indoor climate, can help organizations to save fifteen percent on their energy costs. To reach this, a partnership between

facility manager and technical manager and/or suppliers is needed (Bekkering, 2015). The investment costs for implementing a BEMS such as Plugwise (www.plugwise.com) in an organisation with 500 working places will be about € 85,000. The return on investment will be less than two years (Craen, 2016).

A problem in traditional BEMS is their user-unfriendliness and the fact that the monitoring and control is difficult due to constantly changing (weather) conditions (Ali & DoHyeun, 2012). Generally the BEMS uses the BMS to extract information about energy consumption and to control the climate installations, taking into account, for instance, the opening times of the building (Advies&zo 2015).

2.3 lity Management Information Systems (FMIS)

A Facility Management Information System provides information on available or delivered facilities serving to support the operational activities within the facility organization. By this, business processes and workflows are structured, managed and automate (Maas & Pleunis 2006). Complaints of the end-users about the indoor climate can be submitted to the FMIS. These complaints come in at the front office and, depending on their nature, they are communicated to the back office, to the customer service or to the supplier. The number of complaints are monitored for a certain period as well as their location, the percentage of complaints that has been handled, the costs that were involved and whether all this meets the required service levels. With help of this information a Facility Manager makes analyses supporting the long-term maintenance decisions and prioritisation of the work. (Verbeek 2015).

2.4 Building Information Management (BIM)

A Building Information Model is a digital three-dimensional building model linked to databases and containing all data for the development, design, construction and management processes. All actors in the building process are adding and updating their specific information into this system. The current developments show BIM is increasingly seen as a network of linked open databases with different building information, this is called Open BIM (Visser 2014).

3 Results of the interviews

Many facility organisations do not deliver the services around indoor climate and energy at the desired level. This is because many facility managers do not have sufficient technical knowledge and information to cope with these services and therefore delegate their responsibilities to the building manager or the suppliers. The building manager has mainly a technical approach and does not have enough knowledge of the end-user to meet his requirements, leading to a poor service

level. Moreover, external building managers may also have other (own) interests (Joostens & Itard 2012). The current generation of Facility Managers are not trained in energy management because it is still a relatively new discipline. Organizations usually do not know how to steer on the optimal energy management in order to obtain the lowest possible energy consumption. Besides the lack of control and knowledge, facility managers miss the access to up-to-date information about the building and its installations. For the realisation of energy reduction, using a building management system, extended with a specialized energy management system gives the best results. However, the BMS is rarely used as a monitoring system and too few analyses are made to detect the underlying causes of discomfort and energy problems and to resolve them. The FMIS, that could also be used for these aims, is also insufficiently used, resulting in the fact that comfort complaints, and faults are not analysed and not linked with the information from the BMS (Cloin 2012).

The current information systems are working in parallel, are not integrated with each other and are not used and managed in an integral way. According to the experts, there will always be and should be different information and management systems in use. In practice, each organization will have to decide which information is managed by which kind of system. An important basic principle is that it does not matter where the information is managed as long as it is being managed. (Visser 2014).

Remarkably, BIM is not used yet in the exploitation phase of buildings. After completion of the building, the organization usually receives the digitised drawings and specifications, and sometimes a BIM model, but, because there are no protocols for information exchange, this information can often not be used. After some time the information becomes outdated and gets lost. When information is exchanged it is mainly information on design (specifications) and construction work, which is not in a useful form for operating the building. If the data was compliant to the needs and the correct information could be filtered out of the system, BIM would be of added value for the facility management and all building information is available in one visual model, whereby it is possible to add or to extract specific information. This information is currently stored in various (analogue) systems and is not available when needed. Many different actors on several operational levels are managing this information, but often it turns out that this information is outdated. It's not clear if revisions, contract modifications, fault history and changes in the control strategies of the climate installations were tracked and communicated to the right stakeholders. The interviews show that the reliability of the information and the speed with which the information can be retrieved is important for all stakeholders (Wessling 2013).

According to BIM experts, a well filled FMIS is a good starting point for a complete BIM database. This means that FMIS and the other management systems will have to find a way towards Open BIM. It is clear that the desired result can only be achieved if the different systems are able to effectively communicate with each other.

Using BIM can lead to savings of 20% on the operational costs. These savings are mainly achieved because of the reduction of search time when tracing the information that is necessary to the efficient maintenance of the building. When implementing BIM in an existing building, the return on investment will be less than two years (Teicholz, 2013). Dutch experts who were interviewed are also sure that there are considerable savings to achieve through the use of BIM because it is expected to make the work more effective (Visser 2014).

Sadly enough facility managers have a lack of knowledge about BIM and its benefits and about how to communicate with technical partners. Additionally the BIM systems from the design and construction phases are not connected to the FMIS systems of the facility managers. That's the reason why a complete BIM model implemented during the operational phase seems too expensive and too complex (Bosch 2014). The full implementing of BIM by facility managers is a (too) big step which for many organizations seems not feasible in the short term. BIM should be seen more as a platform for cooperation between all parties involved than as a technical system. All actors must then agree to support the same common objectives. The research shows that phased implementation of parts of BIM during the operational phase is likely the most feasible way.

4 Conclusions and recommendations

To ensure the transition to low-energy buildings, it is urgent that organisations commit themselves to a building information management system with good collaboration agreements between all actors who play a role in the management of the building and the indoor climate. Open BIM can provide the information that is necessary for the operation during the entire lifecycle of a building.

In order to achieve an advanced building information management system like BIM for existing buildings, it is important that BIM is introduced in small steps. Existing building information will be digitized and should be linked to existing information systems. It is important that clear aims, an input protocol and unambiguous procedures are established first.

A good start is to couple the relevant information about energy consumption and comfort from BMS to the user information from the FMIS in order to manage and steer on comfort and energy use. After that a more detailed separate energy management system can be added.

Finally, 3D up-to-date drawings files can be added to create an advanced and well-accessible building information management system (operating BIM) in which a consistent and clear overview of bottlenecks in the energy consumption and management of space and comfort is given, leading to improved steering possibilities. The important thing here is to show through small successes in the short term that benefits can be achieved (Visser 2014).

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'ZERO TRANSITION' IN HOUSING AREAS PROSPER BY BALANCING MUNICIPALITY- CONTROL AND CITIZEN-PARTICIPATION

To speed up climate neutrality of Dutch cities the national government started 4 neighbourhood housing area innovation projects concerning citizen participation (IKS2). The participatory fascination of these projects lays in the gradations of citizen participation being: thinking-along, joining-in and investing-in. The conclusion of analyzing these projects are: 1. The sustainable results of citizen participation are the best in situations of thinking-along and investing-in as long local government manages the control, and 2. Local actors have to be taken along from the start of such municipality projects, because they motivate others.

1 Introduction

1.1 The IKS2 Dutch 'Climate-Neutral City' innovation program analyzes set-up

The Dutch 2010 innovation program for speeding up the transition of cities towards climate neutrality 2010 (IKS) (Ministerie-VROM, 2009) contained 20 projects at the start (IKS1) from which 8 projects ended up in project realization (IKS2) being innovation project realistic enough for execution. In 2013 the evaluation of the IKS program (Boon et al., 2013) scanned climate neutral activities in 55 of the 400 (2009) municipalities working on climate neutrality. Lessons learned from failures scanned by group session showed to be: plan a path, arrange enough budget, make the target clear and 'last but not least' work together the local citizens included. The final conclusion of this 2013 research is that municipality civil servants and citizens by acting together can make the difference between failure and success.

4 of these 8 IKS2 realized innovation projects concern citizen participation in neighbourhoods, and these are not evaluated on conditions for successes and failures yet. The other 4 are respectively involved in public transport, young and green entrepreneurs and agricultural development. From the 4 neighbourhood projects can be learned how citizen participation can contribute to climate neutrality of cities. This because these are thematic comparable, they started and finished in the same period and all concern citizen participation from the beginning to the end.

TITLE	AUTHOR	ORGANIZATION	MAIL ADDRESS
'Zero Transition' in housing areas prosper by balancing municipality-control and citizen-participation	Dr. ir. drs. Fred C. Sanders CO-AUTHOR Prof. dr. ir. Arjan van Timmeren	TSMbs Enschede Enschede, the Netherlands and TU Delft Delft, the Netherlands	f.c.sanders@tudelft.nl tel. +31 6 54773140

108 Unfortunately the sample of these 4 IKS2 innovation projects is limited in numbers. However these concern interesting Dutch examples of 'climate neutral' innovations coupled with citizen initiative for the period that such initiatives started up at the beginning of this century. Therefore these projects are analyzed in 2015 on the moment that the evaluation report became available. To compensate the poor project availability the dissertation called 'Sustainable development through resident's collective initiatives' (Sanders, 2014) is used as an add-on scientific base.

The research question that fits to this bundle of IKS2 projects and the challenge of climate neutral cities is: *How did the depth of citizen participation contribute to the success of the first innovative showcase IKS2 projects in the Netherlands?* The casestudy research is done by file-search, key-person interviewing with the the above mentioned dissertation (Sanders, 2014) as the 'body of knowledge' for the research methodology, analyzes and conclusion making.

This dissertation 'body of knowledge' for the research does include the modelling of citizen participation showing the following hierarchy: thinking-along, joining-in and investing-in all stages of exceeding citizen empowerment, based on literature search among them research concerning societal participation (WRR, 2012) and the relation forms of citizen initiatives with local governments (Tonkens, 2009).

Each of these stages of participation should be defined as follows:

Thinking-along: a passive citizenship, citizens reflect and advice by accepting governmental initiatives.

Joining-in: a passive citizenship, citizens participate in and support government initiatives.

Investing-in: an active citizenship, citizens take responsibility for initiatives dealing with government.

1.2 The IKS innovation program projects concerning citizen participation

Focusing on these 4 neighbourhood sustainability innovation projects (IKS2) these are spread over the Netherland's country, concern big and small cities, all concerning renewable energy and neighbourhood integration by citizens participation. Each project with its own targets, neighbourhood context, control action-prospects and results, as given in the following framework and project details:

IKS2 Projects	Sustainability target of the project	Neighbourhood context	Control action-prospects during the project	Results of the project
1. Heerhugowaard 'De Draai' ¹⁾ (¹⁾ see next page)	<ul style="list-style-type: none"> • CO2 neutral • 100% renewable energy • passive houses • no windmills 	<ul style="list-style-type: none"> • 2,700 houses • community set-up 	<ul style="list-style-type: none"> • sustainability as part of housing contracted • facilities due to 1) neighbourhood NGO 	<ul style="list-style-type: none"> • sustainability result for large extent by placing windmills • green-water areas
2. Rotterdam 'Heijplaat'	<ul style="list-style-type: none"> • 2020 climate neutral • social targets • 100% rewable energy 	<ul style="list-style-type: none"> • residents en enterprises together • kitchen-garden projects 	<ul style="list-style-type: none"> • monthly meetings • government brought higher education to the neighbourhood 	<ul style="list-style-type: none"> • small household initiatives • windmills for 80% of the renewable energy
3. Wageningen 'Solar-energy'	<ul style="list-style-type: none"> • 2030 climate neutral • focus on solar energy 	<ul style="list-style-type: none"> • collective resident project • solar panels on roof of enterprises 	<ul style="list-style-type: none"> • started a NGO for local solar-energy 	<ul style="list-style-type: none"> • 150% of the target in 2015
4. Zoetermeer 'Solar-energy'	<ul style="list-style-type: none"> • 2030 climate neutral • city wide initiatives • wide range of targets 	<ul style="list-style-type: none"> • with residents and • with enterprises 	<ul style="list-style-type: none"> • subsidizing investments of residents • lower tax for investing enterprises 	<ul style="list-style-type: none"> • target 2010 -6% done • startup of solar energy cooperation on roof neighbourhood school

Figure 1: targetting of the 4 Dutch IKS2 neighbourhood housing projects (www.rwsleefomgeving.nl)

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'Zero Transition' in housing areas prosper by balancing municipality-control and citizen-participation	Dr. ir. drs. Fred C. Sanders CO-AUTHOR Prof. dr. ir. Arjan van Timmeren	TSMbs Enschede Enschede, the Netherlands and TU Delft Delft, the Netherlands	f.c.sanders@tudelft.nl tel. +31 6 54773140

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¹⁾The 'De Draai' development is the delayed copy spin-off project of the 'City of the sun' project of Heerhugowaard municipality. Because of the delay results are not available yet. Therefore the results of the 'City of the sun' project are filled-in in the two columns to the right concerning 'control action-prospects and results, both purple cursive given to make this choice visible. The content is taken from the dissertation 'body of knowledge' mentioned before.

Information on the 4 IKS2 project situation and details:

Heerhugowaard 'De Draai', a new planned neighbourhood for 2,700 houses situated à 50 km north of Amsterdam, was planned to become and renewable energy-cost free neighbourhood. Due to the economic crises (2008-2014) the target of the project was changed, becoming 'more or less' a copy of the former realized sustainable neighbourhood 'Stad van de Zon' of Heerhugowaard. Therewith the target becomes CO2 neutrality by solar and wind energy. All the investments in renewable energy are brought in a community ownership by the residents as part of their housing contracting.

Rotterdam 'Heijplaat', an in 1904 established neighbourhood counting 1,600 residents, was originally built to house shipyard workforce. As a project of 'Rotterdam Green' the target for this neighbourhood became climate neutrality in 2020. The project focus was stimulating the residents in a group process.

Wageningen, hometown of the University of Agriculture, counts 38,000 residents. To reach climate neutrality in 2030 the municipality started stimulating the placement of solar cells in 2011 targeting the production of 2 MW. The focus of the project was civilian initiative for which a local solar energy co-operative (NGO) was started. To start progressively the roof of the research institute MARIN would be filled up with solar cells by municipality investments.

Zoetermeer city counts 125,000 residents and is positioned as a suburb of The Hague city since 1962. In 2007 the municipality started a diversity program of sustainability projects to establish 30% CO2 reduction in 2018. In 2010 evaluation proved a result of 8%. In 2011 the city started the lesser successful advanced campaign 'pleasure with energy reduction' with new initiatives (solar energy, isolation, double glass investments) for residents en enterprises. Recently a promising solar energy cooperation started giving out bonds for placing solar panels on the roof of schools and other public buildings.

2 Research

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2.1 The four IKS citizen focused projects on citizen participation unraveled

The four IKS2 projects show to have quite similar targets, initiatives of the projects are all neighbourhood coupled, and solar energy is the primarily choice into renewable energy. The differences lay in the organization of collaboration of the initiatives. First the initiators show to be professionals in all of these project cases. In the Heerhugowaard the complete project was set up by civil servants. In the Zoetermeer and Wageningen projects civil servants started up an NGO with local professionals. In the Rotterdam situation local government contracted the energy company to take the initiative. In all of these four projects the citizens were invited to join one of more of the initiatives within the project, to have a personal contribution, create own organizations for their activities, or even to take over initiatives or the project. For the results and what led to these, and the 'here for so-called' depth of participation see figure 2.

IKS2 Projects	Involvement of the citizens	Sustainability by citizens	Organizational citizens choices	Depth of citizen participation
1. Heerhugowaard ⁽¹⁾ 'Stad van de Zon' (1) see next page	<ul style="list-style-type: none"> the solar/co-generation are owned by residents by house contracting the residents ass. influence public space and societal facilities 	<ul style="list-style-type: none"> result on energy bill due to relatively passive participation into 5MW solar energy 	<ul style="list-style-type: none"> no choices in energy solar/cogeneration windmills placed unless resistance unfluence on societal facilities 	<ul style="list-style-type: none"> Joining-in
2. Rotterdam 'Heijplaat'	<ul style="list-style-type: none"> the residents being consumers in a community program by energy compagny 	<ul style="list-style-type: none"> minor results: energy displays in the houses 	<ul style="list-style-type: none"> residents ass. got influence on the community program not on the products 	<ul style="list-style-type: none"> Thinking-along

Figure 2 (part 1): choices with citizens made in the 4 Dutch IKS2 neighbourhood projects

IKS2 Projects	Involvement of the citizens	Sustainability by citizens	Organizational citizens choices	Depth of citizen participation
3. Wageningen 'Solar energy'	<ul style="list-style-type: none"> citizens were invited to participate in solar investment strategies 	<ul style="list-style-type: none"> citizens participated in network stimulating others taking initiative 	<ul style="list-style-type: none"> citizens groups were free in organizational choices 	<ul style="list-style-type: none"> Investing-in
4. Zoetermeer 'Solar energy'	<ul style="list-style-type: none"> initiative taken by citizens after the local governmental program had clashed 	<ul style="list-style-type: none"> the citizens were invited into crowdfunding for solar energy 	<ul style="list-style-type: none"> the crowdfunding organized financing of a cooperation that took the initiatives 	<ul style="list-style-type: none"> Investing-in

Figure 2 (part 2): choices with citizens made in the 4 Dutch IKS2 neighbourhood projects

The results of these 4 Dutch IKS2 climate neutral projects according to citizen participation are:

Heerhugowaard 'Stad van de Zon' (City of the Sun: www.heerhugowaardstadvan-dezon.nl) being the expected blueprint for 'De Draai' project, contracted all the sustainability investments as part of the house contracting. Therewith the house-owners (individual house buyers and social housing companies) became community shareholder in a neighbourhood energy plant included total of solar panels placed on their own houses complete with a cogeneration fabric. The production of solar energy with 5 MWp is à 50% more than locally needed, the residual energy is delivered to the next-door municipalities Alkmaar and Langedijk. Although the residents had less choice in their sustainability participation, the results got many awards and some spin-off projects are still in development: in spring 2015 some 200 household started scouting new sustainability innovations (www.energiekoplopers.nl).

Rotterdam municipality in 2010 invited an energy company to bring the isolated neighbourhood 'Heijplaat' by participation of the residents sustainable, this is consistent with the Rotterdam 'Green agenda' (Eneco, 2012). The target was to sell a 100% renewable energy contracts to the households and transform the old

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shipping wharf into a place for schooling and start-ups. One of the stimulating actions was the introduction of energy displays in the houses. The evaluations of 2014 showed that unless some results, the activation of the residents failed (Damen, 2014) (wijkbewoners, 2014).

Wageningen 'Solar-energy' project in 2014 reached the result of 2.6 MWp à 30% beyond the target of 2 MWp (Botman, 2010), and another 3.0 MWp is in preparation (Coenraads, 2014). From this 2.6 MWp the largest part of 65% concerns individual household investments, four times more than predicted. Social housing corporations reached 0.5 MWp almost 20% of the result in cooperation with their tenants. Recently in 2015 a local solar energy cooperation started with placing 722 solar panels for delivering 0.2 MWp on the roof of MARIN research institute and filling up a number of roofs of the university is in planning. Local Government's expectation is that this cooperation will realize 2.2 MWp on roofs and free land space in the coming years. The result will be that the citizens of Wageningen will be the factor for making the municipality climate neutral, individually (65% in 2014 what still means 30% of 5.6 MWp) and cooperative (20% in 2015 and 50% of the 5.6 MWp). The initiative of the local municipality to work together with sustainability driven key people from university, enterprises and society facilitating individual and cooperative initiatives of businesses and citizens proved to be very successful in 2014 and beyond, based on the plans that have been started. (www.zonne-energie-wageningen.nl/29-juli-cooperatief-zonne-energieproject-op-dak-marin)

Zoetermeer IKS2 has been stopped before it started. The municipality was confronted with local enterprises that did not participate, wind turbines showed to be conflicting with the new wood-planting in the surroundings of the municipality, and most of the houses of the social housing companies being high-rises (6,000 social rental houses) appeared to be unsuitable for placing solar panels. As a result of all these blockades a group of locals started the 'Duurzame Energie Coöperatie' (sustainable energy cooperation: www.dexo.eu) with 100 solar panels on the roof of a secondhand shopping complex, and other expansion projects are in planning. In this concept citizens participate financially by buying bonds into crowdfunding.

2.2 The IKS Action-Prospects concerning citizen participation extracted

The sustainability results (norm: the quantity of MWp renewable energy produced on the location) of these 4 IKS2 projects show to be the best at Wageningen 'Solar energy' projects and Heerhugowaard 'Stad van de Zon' (substitute for 'De Draai' project) and, the lesser scores the Zoetermeer energy cooperation. The worst result is for the Rotterdam 'Heijlplaat' project. For the results follow the 'green line' of figure 3.

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For each of these counts that it's the municipality that took the first initiative, after which citizens joined or reacted and in 3 out of 4 of these IKS2 projects by taking initiative(s) themselves. Notable thereby is that the Rotterdam 'Heijplaat' initiative by which the municipality laid the initiative to the local energy company for inviting and stimulating the citizens (for joining-in) to start up initiatives, did not succeed well. The only sustainability results of the 'Heijplaat' project came from local government investments solely, by solar panels on the roof of the old wharf mainly and wind-mills nearby in the green field. The citizens remained in the consumer position in which they acted little to none. Thereby the control situation of this project became diffuse, did not laid by government and was not with the citizens.

For the other 3 projects concerning the cities Heerhugowaard, Wageningen and Zoetermeer, it was clear from the start that the control function laid by government. In the Heerhugowaard situation the citizens participated by reflecting and advising (thinking-along), they never had influence on the major choices. In the Zoetermeer and Wageningen projects the municipality managed clarity too, the municipality managed the control function by making clear that not the municipality though only citizens and citizen group would be with making the initiatives by investing themselves (investing-in). The coupling of these 'stages of participation' with the sustainable results of the project are showed in figure 3 too, by adding these to the horizontal axis of 'citizens invited to take more initiative'.

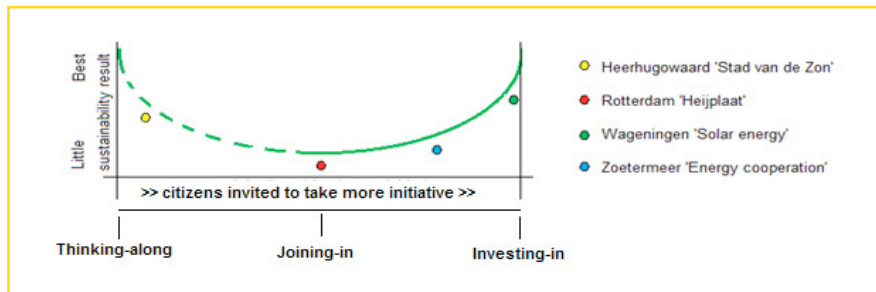


Figure 3: Square diagram of the 4 IKS2 project

Explanation of the figure: The project results are sketchy given position in a square with vertical the sustainability results and horizontal the stages of citizen participation: thinking-along, joining-in and investing-in as they were managed in these project by the municipalities concerned. Therewith the Heerhugowaard project 'Stad van de Zon' project with second best results with thinking-along participation is positioned highly to the left. On the right high positioned is the Wageningen 'Solar energy' project with the best sustainable results by which the citizens were invited to

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	CO-AUTHOR		
	Prof. dr. ir. Arjan van Timmeren		

115 invest and organize themselves. To the right with lesser results Zoetermeer 'Energy cooperation' is positioned. In the center with little result in a joining-in situation the Rotterdam 'Heijplaat' project finds its place. The green line in the figure accentuates the trend-line from which the line to the left is interrupted because of lacking data.

3 Conclusions

The Wageningen, Heerhugowaard and Zoetermeer IKS2 innovation sustainability projects show that the best results are managed in situations where the collaboration of the local government with the citizens is clearly organized, and practically it's the municipality that starts up the projects context settings. Although the model of collaboration from the municipalities point of view was different in the Wageningen, Zoetermeer versus Heerhugowaard situation, respectively a thinking-along and investment-in concerning the citizens way of participation. The Rotterdam 'Heijplaat' case showed that a diffuse situation of control from the municipality as by joining-in participation is a worse base for success. A conclusion that can be confirmed by the first 'blocking dilemma' out of the dissertation mentioned (Sanders, 2014): 'citizens do not take sustainability initiative from-out themselves easily. The corresponding dissertation's action-prospect to this conclusion is: 'that municipalities should know the citizen's pull-motivations to stimulate sustainability initiatives'. Apparently Wageningen, Heerhugowaard and Zoetermeer conceived the motivating factors of the citizens participating well. In the Wageningen and Zoetermeer situation the municipalities invited their citizens to invest in solar panels mainly, which was embraced actively. In the Heerhugowaard situation all the choices of sustainability were made by the municipality beforehand, before the houses were given in sale or rent. Still the citizens were free of choice searching a house in this neighbourhood 'City of the sun', the clearness of having less-choice apparently spoke to their motivation. Citizens need clarity of their situation that is the general conclusion from these 4 IKS2 projects.

Secondly these 4 IKS2 cases show that the best results develop in situations where the local municipality takes the first initiative, to facilitate local actors. The successful Wageningen and Heerhugowaard projects show to the most that seeking collaboration with citizens starts by finding and motivating local actors. These actors can be civil servants, citizens and local entrepreneurs. From the dissertation mentioned we can learn that these actors generally act in and around places: in a street, a condominium, in a neighbourhood, from a community building or a school as can be said in 'small urban areas'. In the Wageningen case with the best sustainability performance as example: the municipality started up a collaborative network with

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local actors, citizens and local entrepreneurs, which stimulated many other citizens to place solar panels on houses and buildings. The Heerhugowaard and Wageningen cases and the Zoetermeer case thereby confirm the in the dissertation mentioned second action-prospect: that local actors organizing 'joint citizen initiatives' called 'frontrunners' are not only citizens, are professionals too.

Finally we can learn from these 4 IKS2 sustainability innovation projects in city neighbourhoods, that motivating citizens to take sustainability initiatives asks more than motivating alone, it is necessary that the context of the project is shown to be under control and local actors are needed for multiplying results.

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TITLE
The digital 3D city model as a base data infrastructure for innovative solutions for the built environment

AUTHORS
Dr. Elger Heere
Ir. Jeroen Mens
Ir. Charlotte Trip
Ir. Kitty Vreeswijk

ORGANIZATION
HU University of Applied Sciences
Utrecht, the Netherlands

MAIL ADDRESS
elger.heere@hu.nl
tel. +31 88 4818317
jeroen.mens@hu.nl
charlotte.trip@hu.nl
kitty.vreeswijk@hu.nl

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THE DIGITAL 3D CITY MODEL AS A BASE DATA INFRASTRUCTURE FOR INNOVATIVE SOLUTIONS FOR THE BUILT ENVIRONMENT

The research group Supply Chain Redesign in the Built Environment of the Utrecht University of Applied Sciences, focuses on, among others, two main topics. At first, there is the topic of the circular city, in which building waste is re-used from demolished buildings into new design solutions for the built environment. Second, there is a focus on the BIM-GIS integration. To know where specific materials are, gives new opportunities, for example for building logistics. As a base for these processes the use of a 3D digital spatial city model is proposed. This model should contain various types of intelligence.

1 Introduction

One of the main topics of the research group Supply Chain Redesign in the Built Environment, a research group of the Utrecht University of Applied Sciences, focuses on the circular city. In this case, it means that city building waste is re-used from demolished buildings into new design solutions for the built environment. To establish this circular city, there is a need of information on various levels in an open source structure. Examples of such data need can be, where and when is what kind of building material needed, and where can building materials be gained by demolishing buildings? For these kinds of questions, a smart 3D city model is proposed. This model should contain various types of intelligences, like GIS-BIM integration and real-time and modelled environmental data. The combination of data creates new, innovative possibilities for the built environment. The goal is to generate added value to cities by combining this information and redesigning buildings and surroundings by using re-used materials from within the city as much as possible, and therefore reduce the use of new material to zero. The city can be seen as an urban mine, where gathered materials can be used for other purposes. By making the city model and its data open source, every party, from individual inhabitants to large companies, can profit and contribute to this open source information structure.

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ORGANIZATION
University of Applied Sciences Utrecht, the Netherlands

MAIL ADDRESS
elger.heere@hu.nl
tel. +31 88 4818317
jeroen.mens@hu.nl
charlotte.trip@hu.nl
kitty.vreeswijk@hu.nl

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The research group Supply Chain Redesign in the Built Environment is planning a research to the use of a 3D city model deliver data and tools to establish a circular city. Research topics will be the possible applications of the city model and the associated functional and data model of it. This paper gives the point of view of the research group on the subject of the city model for the circular city. The research itself is still in its exploration phase.

This paper starts with an explanation of the term circular city and its main components, that is BIM-GIS integration and its open source structure. After that, the role of the 3D city model will be explained.

2 CIRCULAR CITY & BIM-GIS integration

The Ellen MacArthur Foundation, a “global thought leader” in the field of circular economy, defines the circular economy on their website (www.ellenmacarthurfoundation.org) as follows:

“A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.”

For the built environment, focus is on eliminating waste through re-use of materials and re-designing building components, systems and logistics. Most materials in the construction industry are part of the technical cycle as defined by the Ellen MacArthur Foundation (2012). This means we should design for remanufacturing and refurbishing to keep components and materials circulating in, and contributing to the economy. Circular systems use tighter, inner loops (e.g. maintenance, rather than recycling) whenever possible, thereby preserving more embedded energy and value. The technical cycle involves the management of stocks of finite materials. Use replaces consumption.

In the context of this paper and the digital 3D city model, a circular city could be described as an industrial and economic system where re-use of products and materials add value to every link in the system. By doing so, it can contribute significantly to a transition zero, for instance by reducing CO₂-emissions as an effect of more efficient logistics.

Within the research group Supply Chain Redesign in the Built Environment research is performed on different aspects of the so-called “circular city”. For instance on

open source developing, designing and constructing small urban areas with re-used demolition waste in the city of Utrecht. And on the benefits and effects of a so-called "circular HUB" within the confines of the city. The authors of this paper would like to refer to other papers of the research group Supply Chain Redesign in the Built Environment as part of the SBE16- Transition Zero Conference, for a more detailed insight in these and other related subjects.

For a circular city it is important to know how many materials and resources are available within the boundaries of a city. Or, as Zhu (2014) states, "[...] location-based information or location intelligence about waste and recyclables and their potential stocks and values can help identify actions to build capacity, ensure an appropriate suite of services is available to communities and assist in site selection of waste collection facilities and the recycling industry in order to maximise economic benefits and minimise environmental impacts." The city can turn into an urban mine, where (used) resources can have a new meaning within the city. Newly developed buildings are being designed by using BIM (Building Information Modeling, a 3D model of a building in which more information is included about the building and the materials) software. A lot of data is already known from existing buildings by other sources such as geographical information and sensors. Within the city there are various data resources that can help us to make the city more sustainable. Resources such as cycloramas (very detailed 3D panoramic photo imaging), point clouds, City Engine, traffic information, etcetera can provide us with very detailed and real-time data. All these different types of intelligence can be combined into the 3D spatial city model, hereby we have the ability to show real time traffic information and real time and modelled environmental data. This combination of data establishes valuable information for the built environment.

If we think of possibilities of the spatial 3D model for the city we can imagine:

- Visualization of the city in real-time
- A design tool such as for how to position solar panels, shadow studies, traffic control in a neighborhood, etcetera
- Predict different types of conflicts in the city (work in progress roads and detours, load too heavy or big for the road, etcetera)
- Warehouse/storage: visualization of materials and resources (visualization of the urban mine)
- A design tool for redesigning the city buildings and its surroundings

- A tool that defines the perfect matchmaking for used materials and products (using the most nearby source)
- A tool that defines an optimization for combining multiple traffic systems (such as cars, train, boats, trucks) for transporting the materials and defines the best route with the least CO2 emission

The visualization of the urban mine makes it very easy to use materials from within the city. Most of these materials have been used in other buildings, infrastructure, industries or products (Cossu and Williams 2015) and can be re-used. Within our research group an investigation has been done to develop a renovation with used materials from another building (in this case from the same owner). This investigation has been done to find out which information needs to be known about a resource and to see if this can be done by comparing different (BIM)models. This comparison can be done using a Building Information Model (BIM), but it can be more valuable if we combine different types of information and distribute this information, in that way we can predict a city without waste.

By linking the information a tool can predict which route and which traffic system is the best to transport materials in the city. Hereby it can be foreseen how the city can reduce its CO2 emission.

3 Open source information structure

Within the research group Supply Chain Redesign in the Built Environment, research is being performed on the phenomenon of open source information structures applied to the built environment. The use of open source structures is essential to a rich, 3D city model and can enhance the establishment of a circular city as described above, in the opinion of the authors. This is the case on different scale-levels, for example:

- On the level of the 3D spatial model as a whole, an open source information structure enables every party to contribute to, and benefit from the information in the model. By doing so, it is possible to gain large quantities of valuable information on different levels, essential to a “rich” and useful model
- The open source structure can also provide a “showcase” on a smaller scale level, by showing (open source) examples of real-time applications for re-used materials and products. The information needed to replicate a certain application is, ideally, unlocked in the 3D city model itself, since it is open source. Precisely because of the fact that the information needed will be available / accessible, the development of such applications will be accelerated

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The concept of open source information structures also gives rise to numerous questions.

For instance, how and by whom can the open source platform of a 3D city model be managed, accessed and maintained? Who will distinguish relevant from irrelevant information? How can the reliability of information be ensured? And how can the model grow, without becoming disorganized, overgrown or chaotic?

A more fundamental question is, what can be understood by “open source” in the built environment? Vardouli and Buechley (2014) question themselves what the equivalent of open source code in ICT is for the domain of the Built Environment. Is this for instance all the information needed to erect a (building)structure? In other words, digital drawings, technical details, planning, calculations and so on? If this is the case, BIM, as described above, will fulfil an essential role within an open source 3D city model without doubt.

At the same time, one can question how an open source 3D city model can truly become accessible and beneficial to “the larger public” and not only a limited group of (professional) insiders. Since for instance using current BIM-software requires professional skills. What implications does this have for the nature, basis, design and infrastructure of the model? To be truly faithful to the thoughts and concept of open source?

Future research and practical case studies on the open source phenomenon / 3D city model must provide answers to the questions stated above.

4 The proposed development of a 3D city model for the built environment

4.1 Why a smart 3D city model?

To make the developments and processes described above efficient, good data management is important. There is a need of data about the buildings, which are to be built or demolished and the surroundings of these buildings, including the infrastructure. A 3D city model is an effective way to manage these data. These models can handle an increasing number of tasks concerning environmental issues, like noise mapping, training simulators, disaster management, architecture, and city planning (Stadler & Kolbe, 2007).

To this city model, thematic data can be added. Examples of these kind of data are noise data, CO2 emission data, data on particulates, etc. Once these thematic data are added to the city model, one can speak of a ‘smart 3D city model’.

The functions and its examples described below are proposed functions. A smart 3D city model as described below has not been developed yet.

4.2 Functions of a smart 3D city model

Four functions of a smart 3D city model can be distinguished:

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4.2.1 Communication function

Graphics commonly have a very strong communication function. A 3D picture has an extreme strong communication function, because the level of abstraction is lowered. Figure 1 is a 3D city model. As one can imagine, the 3D picture is much more suitable to make a (mental) picture of the specific part of Berlin than a 2D picture, and is therefore more efficient in communication about the city. Especially when the city model is used by various parties, with different levels of map reading skills, a 3D view of the city is essential.



Figure 1: Berlin 3D city model. Source: <http://www.3dcontentlogistics.com/en/solutions/demos/berlin-3d-city-model-smartmap-web/>, seen December 2015

4.2.2 Data matching function

The second function of the city is a model for matching of data and tools. In the proposed city model, data and analysis tools are stored elsewhere on a server and can be retrieved by the model by web services. The integration of BIM (Building Information Modeling) data with geographic information can be an example of this. The BIM data is on the server of the owner of the data. When needed, the data can be retrieved into the city model and can be combined with other data, from other sources, for example environmental data. Cheng and Das (2014) provide examples of the use of web services for Building Information Models.

4.2.3 Analyses function

The strong part of a GIS (geographical information system) is its analysis functions. These functions can also be added to the city model.

An example of the analysis function of a smart 3D city model can be found in a project of the city of The Hague, in the Netherlands. Here they are working on a 'smart environmental plan'. This is a 3D city model, which contains all the legal rules on building on the specific area. An architect has to make a building design in BIM, which he can upload to the model. The city model compares the BIM model with the legal rules and gives immediately a 'go' or 'no go' for the development of the proposed building (Erinkveld & De Wit, 2015).

4.2.4 Planning Support function

When the functions described above are used in urban planning or urban management, then there is a fourth function of the smart 3D city model, which is a planning support function. The city model helps planners and others to plan, design, maintain or manage urban development or urban processes. To operationalize this planning support function, the smart 3D city model must contain:

- Highly detailed 3D views
- Calculation models on various topics, such as noise, CO2 emission, etc.
- The data necessary for the analyses

Figure 2 shows an example from a Planning Support System (PSS) of the city of London. The PSS contains a 3D city model, data and the calculation rules, necessary for thematic analysis.

See next page.

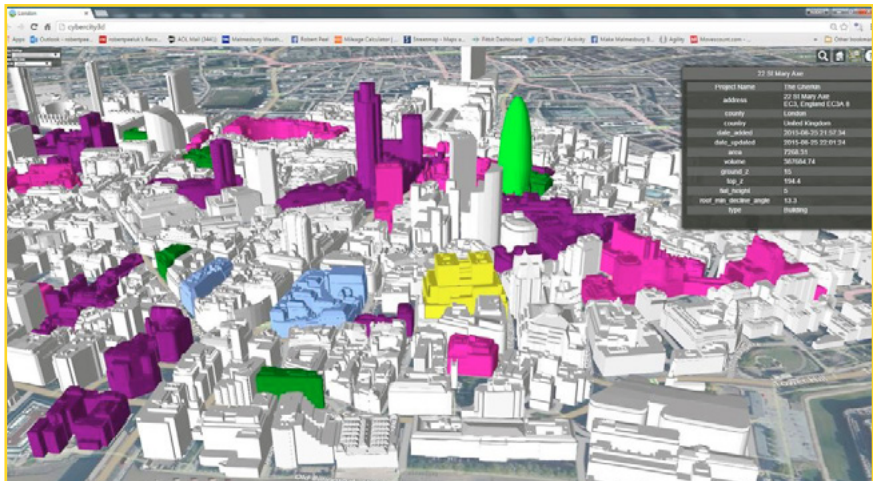


Figure 2: Thematic information displayed on a 3D city model and tools for planning activities.
Source: <http://www.geoinformatics.com/cybercity-3d-creates-3d-interactive-maps-to-help-cities-visualise-their-future>. Seen: December 2015

For urban mining, Zhu (2014) considers some serious data problems, among them data accessibility and data availability. To solve these problems, Zhu suggests to set up a specific national spatial data infrastructure to support data mining. The proposed smart city model can be considered as a start of setting up a data infrastructure for the circular city, albeit at local level instead of national level.

5 Conclusions

In The Netherlands much attention is paid to the development of 3D city models. In October 2014 a 'roadmap 3D' was published, which has as goal to initiate and coordinate 3D development. The outcome of the roadmap was a manifest, in which several 3D initiatives are described. The manifest had been signed by both governmental, scientific and commercial parties (Stoter, et. al, 2014). Although not (yet) involved with the manifest, the research group Supply Chain Redesign in the Built Environment of the Utrecht University of Applied Sciences wants to contribute to this development by realizing a data infrastructure for the circular city. The research for the setup and use of the smart city model hasn't started yet. With this paper we would like to share our vision on the city model as a data infrastructure.

The proposed smart 3D city model will distinguish itself from a traditional city model by adding data and analytical tools to the model, like BIM data or environmental data, so that the city model can be used for communication, analysis and research and decision making purposes. The advantages of using the smart 3D city model in urban planning are:

- The views of model can be of a lower abstraction level, and therefore, it can be used by everybody
- It can contain a lot of data, which improves (when used properly) the quality of the analysis
- The environmental calculation models are available to all the actors, involved with urban planning, not only to the urban planners or the owners of the models

There are a lot of 3D city models available, but none of them contains so much data and functions as our proposed model or is available to a large public. At this moment we are trying to create a network of possible partners (local government, commercial companies, universities), which gives us input in what data and what functions are needed. This position paper will be the start of our research and we hope that we can collect more evidence of our paper with collaborating partners. In this way, the expectation is that the goals of the circular city will be achieved faster and more efficiently.

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TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
The digital 3D city model as a base data infrastructure for innovative solutions for the built environment	Dr. Elger Heere Ir. Jeroen Mens Ir. Charlotte Trip Ir. Kitty Vreeswijk	HU University of Applied Sciences Utrecht, the Netherlands	elger.heere@hu.nl tel. +31 88 4818317 jeroen.mens@hu.nl charlotte.trip@hu.nl kitty.vreeswijk@hu.nl

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DEVELOPMENT OF AN EDUCATION MODEL BASED ON THE BUILDING LIFE CYCLE

This paper presents a model to link civil engineering education into a building life cycle process and describes how the model will be applied in two sustainable building projects. In the building life cycle based model, the studies and courses are linked to a real construction process from which the essential study packages can be selected. The education reflects best practices when the important issues related to working life are highlighted.

The two sustainable projects will be a real study environment for students. Kakola is an old prison property that will be repaired mainly for residential use. Circulation economy and resource effectiveness will specifically be addressed in the teaching of renovation. The new Kupittaa Campus building, currently under design, enables us to combine civil engineering education with the actual construction of teaching spaces intended for own use. Sustainable aspects like energy effectiveness and adaptability, and multi-purpose spaces are essential in the project.

The preliminary results of the first case project Kakola are promising. The collected feedback shows that motivation of students is high and learning outcomes are seen as better course grades.

1 Introduction

The purpose of this study is to present a model to link civil engineering education into a building life cycle process and to describe how the model will be applied in two sustainable building projects. Traditionally, civil engineering studies are presented as a list of different courses in a paper or electrical format. The catalog-like format does not necessarily create a very clear picture of the whole learning process, which includes as well basic and professional studies as the elective studies, practical training, projects and thesis work. It may be unclear for the student in which phase of a construction process the selected course information is needed and how different studies are related.

There are several factors determining the content and methods used in education of civil engineering. Objectives of the education are naturally based on the demands of working life. Furthermore, there are specific qualifications in building planning as well in site supervision and management based on law and Complementary Building Act and Code. (Land Use and Building Act, 1999)

One objective of the legislation and the authority steering is to promote sustainable development. Both construction and environment has to be maintained in a manner that meets the standards for health and safety and does not ruin the atmosphere of the surroundings. A building shall satisfy essential technical requirements and be ecologically sustainable. (Land Use and Building Act, 1999). During the past years there has also been more attention to the environmental requirements in construction, not least because of the climate change.

There is also a need to develop more effective learning methods to replace the traditional forms of teaching like lectures. Turku University of Applied Sciences (TUAS) has a profile in multidisciplinary innovation pedagogy, where entrepreneurship, applied RDI activities and internationality are linked to teaching in order to support innovations that benefit working life. Innovation pedagogy is a learning approach that defines in a new way how knowledge is assimilated, produced and used in a manner that can create innovations (Kairisto-Mertanen et al, 2012). Innovation pedagogy is based on customer-oriented and multi-field needs of working life; it integrates applied research and development and entrepreneurship with education in a flexible way; and promotes regional and international networking. (Kettunen, 2011)

This paper is organized as follows:

- To define the content and location of individual courses in a building life cycle
- To compare the objectives and contents of study courses to the building specific qualifications (competence requirements in accordance with the Government Decree on the determination of difficulty classes of building design and other parties tasks, 2015)
- To take into account the requirements of sustainable development in a building life cycle

- To present the basis for a new model in two sustainable case studies; Kakola-prison and Kupittaa Kampus to analyze the applicable teaching methods in accordance with the innovation pedagogy

The innovative approach of this paper is to consider studies and the demands of sustainable building as a natural part of building life cycle. By integrating studies into two multi-years projects the requirements of sustainable building will be taken into consideration more effectively.

2 Life cycle model as a basis to development content of civil engineering education

The civil engineering degree programme contains a total of 240 ECTS including basic and professional studies, elective studies, project work, training and a bachelor's thesis. The programme provides students with versatile knowledge of design, manufacture, construction and surveying in their specialization alternative to be able to work in different professions in the construction business. A significant part of the studies such as project work, training and thesis are usually undertaken in construction industry.

In a model based on building life cycle the studies are regarded from a point of real construction process and its phases (Fig. 1). Main phases in the construction process are project definition, design, construction and maintenance (Rakennustietosäätiö, 1989). After completion of a building, the longest part of its life span containing use, operation and service starts. During this phase, some renovation and repair work should also be carried out.

Content of studies is defined to meet the essential stages of working life in building life span. The study courses are aimed to locate within a building life cycle taking into account the most suitable and natural location in the span. The first two years studies contain basic studies like languages, mathematics, physics and basic technical studies. The purpose of these general studies is to create a basement for a deeper learning. Professional studies can be divided into common technical studies (3. year) and professional specialization studies (3. & 4. years) Students can choose their professional specialization out of the three options available in building construction: Structural Engineering, Production Management or Real Estate Management. Fourth alternative is to specialize into Community Infrastructure Engineering.

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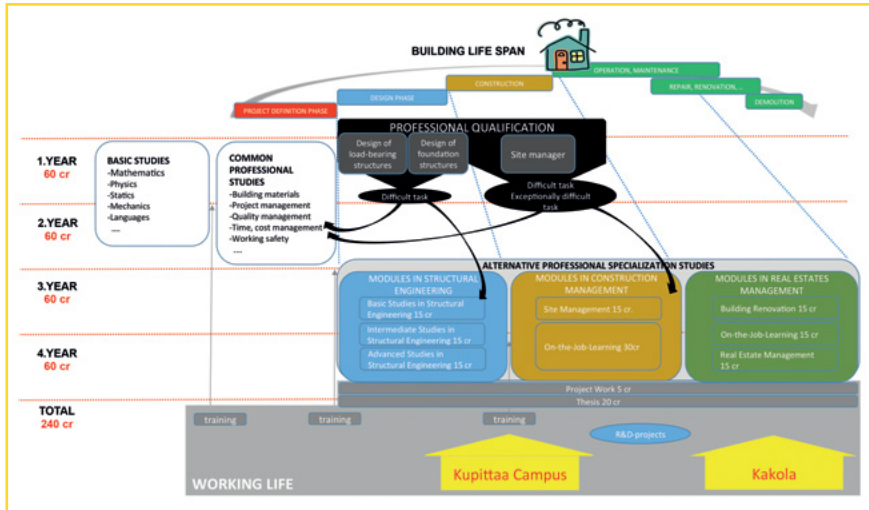


Figure 1: Civil engineering studies and a building life cycle

All studies have been assembled in 15 credit modules. A module should contain studies consisting of the same subject or topic. For example, each specialization consists of three different modules with a total number of 45 credits. Each separate specialization module contains topics related to a focused profession. Furthermore, there is a project work with 5 credits and a final thesis with 20 credits. The optional studies (30 credits) are hoped to consist of studies which support the chosen professional specialization.

The building life cycle based approach is in a line with the curriculum guidelines. The studies should be knowledge based, e.g. the studies reflect the requirements of real working life. The model makes education more transparent and eliminates duplicate studies. The model also emphasizes the essential things in working life such as the requirements based on the professional qualifications. In Finland, a party engaging in a building project shall ensure that the building is designed and constructed in accordance with building provisions and regulations and the permits are granted. The party shall have the necessary competence to implement the project, as required by its difficulty, and access to qualified personnel. (Land Use and Building Act, 2014)

The competence of the parties such as the principal designer, special designers and site manager is based on training and experience. The qualifications required depend on the adequate competence of a party in proportion to the difficulty of the project

concerned. According to the guidelines and decree of the Ministry of the Environment, the difficulty classes of tasks can be classified as (Ministry of the Environment, 2015):

- Minor (simple building, max. 1 floor, <25 m², for example shed, small shelter)
- Conventional (<2 floors, <300m², e.g. single family house)
- Difficult (3-12 floors, over 300 m², e.g. residential apartment house)
- Exceptionally difficult (more than 12 stories, extra large, e.g. shopping centre, hospital)

A designer or other party must be a natural person. To achieve the necessary qualifications, the party has to obtain the required training or education. For each task, there are specific studies related to the task under consideration. In the Ministry of the Environment guidelines on the qualification of building designers and site managers, the required degrees and needed studies with credits are presented. (Ministry of the Environment, 2015)

A completed degree programme in civil engineering in TUAS provides the qualification of a Bachelor of Engineering. Depending on the chosen studies the following training levels for the requirement tasks will fulfill:

- Site manager in a conventional task for all students (40 cr)
- Site manager in an exceptionally difficult task for students specialized in production management (45 cr)
- Designer of load-bearing structure in difficult task for students specialized in structural design (40 cr)
- Designer of foundation structure in difficult task for students specialized in structural design with studies connected foundation structures (40 cr)

The leading idea is that the requirements of sustainable building will be integrated inside civil engineering studies, i.e. sustainable building is not a separate ideology but a natural part of the building life span and education. First, some of these requirements are based on legislation and must therefore include education. For example, energy demands are noticed in building permit process and they are observed as a part of the course "Building Design of Family House". Energy certificates have been used in Finland since 2008 in almost all new constructions. The

structures and components of a building must meet certain u-values and an energy certificate has to be presented (National Building Code of Finland, 2012). Regulation based on sustainable aspects also affects studies related to production planning, for example in waste management on site or planning of a demolished building.

Also other sustainable building features will be acknowledged as a natural part of a building life span. The life time and carbon footprint of different building materials have been taken into account in particular study courses. In building procurement, Lean-philosophy supporting resource efficiency has been addressed.

Hence, specific cases of sustainability building have been applied in many project work or thesis, for example different energy houses and their materials are compared from the point of low-energy or zero-energy housing. Students can also gather optional studies related to sustainable development from other degrees, for example in the Energy and Environment degree.

3 Applying model in two sustainable case studies

3.1 Kakola – old prison area

Kakola is a former prison facility locating on a rocky hill in central Turku. An area of 40,000 building square meters consists of several brick and stone buildings. Kakola served as a prison until 2007 and was empty until summer 2015 when it was sold to Verkaranta Ltd. The property will be repaired mainly for residential use but also other alternatives are under consideration, for example spa, hotel, restaurant, bakery or interactive museum. Kakola is protected under law which sets strict requirements for the use of spaces and facade. (Senaatti, 2007)

In autumn 2015, Verkaranta Ltd and TUAS made an agreement of a co-operation to use the Kakola facility in studies. Main idea is to utilize the facility as a learning environment. In civil engineering education this means especially possibility to combine renovation studies into old challenging building target. Instead of a single project the studies can be combined with multi-year project. The planned schedule of five years will enable to follow construction works by connecting them into different separate study courses. This means continuity when students can see the different stages of a repair project.

Sustainable development aspects like circulation economy and resource effectiveness are highlighted in the Kakola project. Circulation economy is realized when empty spaces will get new purposes. From the point of energy efficiency, an objective is to store heat in a massive brick wall structure. On the contrary, in summer time it would operate for cooling of spaces. Location of the waste treatment plant of Turku inside

the rock under the Kakola hill offers a possibility to utilize waste heat of the plant as extra energy source.

By connecting the real renovation building for teaching the requirements of innovation pedagogy will also be realized. Learning environment is authentic building with its demands. The theory of different studies can be reflected in practice in planning of repair, demolition, repair work etc. Other study methods based on working life are different project works like condition assessments, humidity measurements or thermal infrared imaging.

An example of an already started co-operation is the Repair Planning course, in which students have gotten existing documentation of Kakola in order to create plans for sustainable repair. For instance, a specific task plan for the removal of contaminated soil was drafted by students.

The inside and outside laser-scanning and test model of Kakola has been launched in co-operation with Aalto University in autumn 2015. This information would be a foundation to create a BIM-model of Kakola.

3.2 WKupittaa Campus – new education building

The new education building Kupittaa Campus is currently under design. Construction works are planned to start in 2017, and the end users should move in during autumn of 2019. The building with a net area of 18,000 square meters is located in Kupittaa campus area besides existing campus facilities. Kupittaa is densely built area which is easily accessible by public transportation. (Turun kaupunki, 2014)

Campus will be developed according to strict ecological criteria using energy-efficient, environmentally friendly and sustainable solutions. Adaptability, multi-purpose spaces and versatility are main objectives in the project. Spaces are not only intended for teaching, but also R&D and enterprise purposes. Building would act as test environment for different solutions like variable wall structures or HVAC-equipment.

An objective is to be an example for energy efficient public educational building in Finland. The building should improve its efficiency by combining several different energy saving solutions. Hybrid energy piles and solar panels on roof and facades are planned to apply as energy sources. Energy will be stored under the building's insulated soil storage. In Kupittaa area there is an intensive ground water flow with unusual higher temperature under the building. By pumping this warmer water it can be utilized in part of heating system.

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Also, the materials and construction methods used should be environmentally friendly. Building components and materials should be easily dismantled and recycled. Wood structures like clt-frame is under consideration because of its low carbon footprint. Some effort will also be put on the development of HVAC-system, for example energy efficiency based on heat recovery from ventilation.

Nordic Ecolabel certification requirements will be aimed to fulfill. The Nordic Ecolabel is the official Ecolabel of the Nordic countries and was established in 1989 by the Nordic Council of Ministers with the purpose of providing an environmental labelling scheme that would contribute to a sustainable consumption. (Nordic Ecolabelling, 2014)

The Campus project enables to combine civil engineering education with the actual construction of teaching spaces intended for own use. Construction processes with different documentation will offer lot of raw material for education of civil engineering. Excellent tool would be to create BIM according to sustainable building. Instead of conventional BIM the aim should be to create 6D-BIM, which would serve for example more complete and accurate energy estimates earlier in the design process. Students should be also allowed to participate to use this Kampus-BIM in education. It would be possible to build virtual learning environment in model and to simulate reality. Digitalization also supports sustainability enabling to utilize different intelligent solutions in energy monitoring or space management.

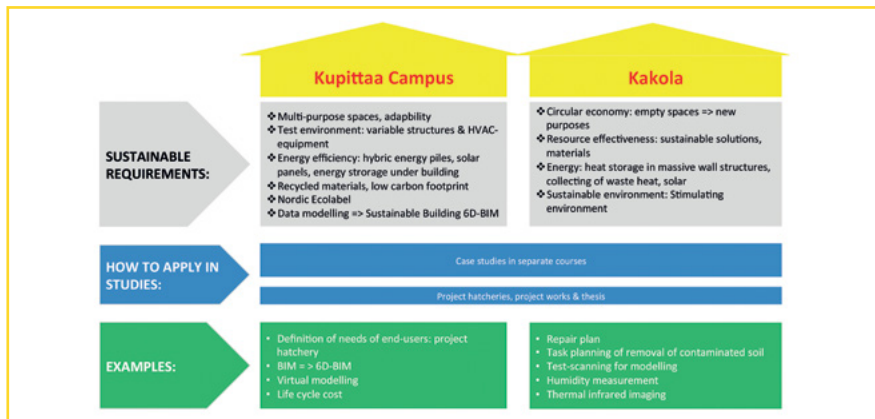


Figure 2: Applying requirements of sustainable building in two case studies

4 Conclusions

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The civil engineering education model based on a building life span offers a new, more practical approach to link the needs of working life with education. It also fulfills the qualification requirements of different building party tasks. Requirements of sustainable building integrated inside the studies in the model will be taken into account in the correct phase of the process.

Although the basis of this paper is theoretical and case projects are just starting, some results can already be presented. First, requirements of sustainable building based on legislation and other aspects have been integrated into studies. This combination has been especially successful in some professional courses related to energy demands.

In both case studies, theory and practice of sustainable building in a balanced manner will be combined. The collected course feedback indicates that the course grades have improved and the students are keen to look forward to future courses because they are already familiar with the Kakola project.

The final results can be estimated when students will graduate and start their work career. The model is expected to increase motivation and to shorten study time. This may also generate new learning objects and educate better professionals for the construction industry.

In the future, development of the model will be carried out based on collected feedback. Also other real projects are aimed to test as a study environment. Although the model is based on Finnish legislation and conditions it would be possible to apply the model on various level also in other countries.

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CHAORDIC STEPPINGSTONES ON THE PATH TO NETZERO ENERGY

Transitions are complex multistakeholder processes that are driven by human behavior, emotions and attitudes. The Dutch innovation program 'Energiesprong' had the mission to transform the built environment to zero energy. In order to do this, new contracts types, a new law and many more subjects needed to be addressed. We needed a flexible yet powerful approach to manage such a process. Based on these experiences, we developed an approach that can be used as a guide in transition initiatives and called it the 'Chaordic Steppingstones on the path to NetZero Energy'.

1 'On the path to ZERO' – transition in eight steps

We have developed a transition process approach based on five years of experimenting with sustainability initiatives in the Dutch government's innovation program called 'Energiesprong' (Literally: Energy Leap) and the Stroomversnelling (The Rapids). The process approach is called: 'Chaordic Steppingstones'. This eight step model is the result of applied experience in more than four major initiatives.

2 The innovation program 'Energiesprong' as a transition approach

2.1 Goal of Energiesprong

Energiesprong was given the goal of drastically reducing energy use in the built environment – including houses, offices and health care institutions.

Intelligent, innovative renovation concepts had to be developed to accomplish this. For construction companies this was an opportunity for rejuvenation. For tenants and building owners it meant increasing independence from unpredictable energy prices and lower living and maintenance costs. Energiesprong aimed at significantly contributing to conditions for effective realisation of this energy transition.

The housing market showed promise for a radically different approach. Large numbers of accommodations have been built systematically and industrially in the Netherlands between 1950 and 1975. Most of those houses are now in urgent need

for an overhaul. Housing renovation had never been attempted or accomplished on this scale before. We are not talking about just a technical challenge, but also a structural challenge that depends on the way the housing market is organized and the way stakeholders and their business models work. The approach of Energiesprong is aimed at radically altering the way of production, financing, consumption and use of domestic energy and housing.

2.2 Pragmatic programming at Energiesprong and De Stroomversnelling

The program was experimental – fitting the transition approach. Many initiatives were initiated, evaluated and redirected when not effective. The approach was very pragmatic and results prevailed over dogma. The only goals were the high energy ambition and scalability of knowledge and solutions.

One of the first Energiesprong initiatives, the ‘Slim&Snel’ experiment, focused on reinventing procurement processes between housing corporations and construction companies as a condition for more radical innovation. The procurement processes were redesigned in favor of bringing together frontrunners and creating space for new ideas. At the start of the initiative, the energy savings ambition was 45%. During the experiment, this percentage increased through steps of 60 and 80 to eventually 100%. In one of the experiments a promising NetZero Energy concept was developed. A problem was the scalability. Market conditions like financial rules and regulations favoured mainstream solutions.

Both the construction and the housing corporation market at that point faced existential threats. The financial crisis had put a complete stop on real estate development, leading to serious financial trouble. Energiesprong proposed a new perspective by stating that the annual 13 billion euros that the built environment burns up in fossil energy can be put to better use by investing it in the houses themselves.

During the 2012-2013 holiday season, a number of mainstream actors started to believe that large scale net zero energy refurbishments was feasible. In spring 2013, four construction companies, six housing corporations and the Ministry of Internal Affairs united in De Stroomversnelling (The Rapids) to jointly renovate 111.000 homes to net zero energy. The goal was to develop the necessary market conditions and to invest in an innovation and industrialization process leading to a radical new alternative. At the time of signing the alliance, net zero energy refurbishments cost about 130.000 euros. Innovation would have to reduce this by half for it to be scalable.

3 Chaordic stepping stones

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What we have learned is that it is possible to program and dynamically manage transitions. Therefore we developed eight ‘chaordic’ steppingstones for the understanding and managing of the dynamic processes in transition (see Figure 1). The word chaordic contains both chaos and order. Every steppingstone represents an important ingredient of your role as an initiator or process facilitator. They are not linearly organized, but cyclical and iterative. It is a method to both be able to respond promptly in a dynamic context and gain increasing profundity the further you are in the process.

We have been inspired by fields such as transition theories, philosophy, procurement, innovation studies and technology studies and developed our practice on-the-job. The chaordic steppingstones are not a result from theoretical studies, modelling and testing but based on practice we have drawn up our experiences and insights.

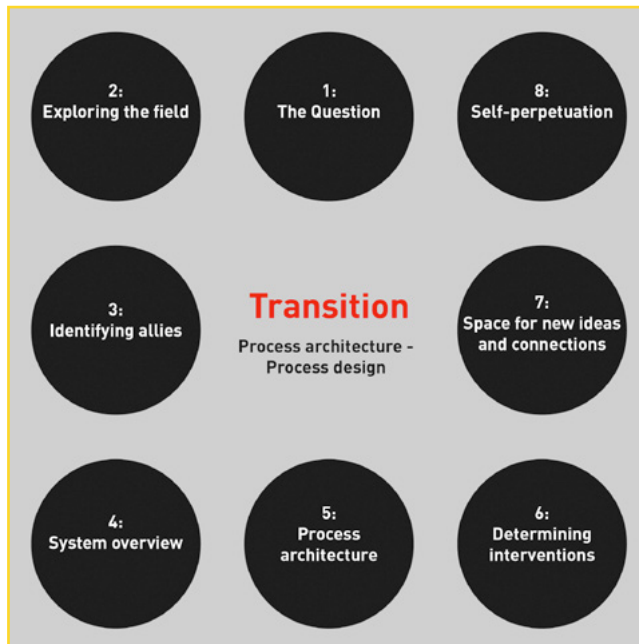


Figure 1: Chaordic steppingstones: transition in 8 steps

Steppingstone 1 – The Question

Steppingstone 1 is about determining the goal and ambition in relation to a transition project, initiative or experiment. To be able to define a transition goal, it is vital to understand the challenge. The goal of Stroomversnelling is for example not the net zero energy refurbishments, but rather reduced dependency on fossil energy and the continued affordability of the Dutch housing market. Take your time to explore this.

Steppingstone 2 – Exploring the field

Steppingstone 2 is about exploring the field at a meso level. What are the larger societal links and developments? What are the relevant laws? Which financial methods are in use? What is the state of technology? The purpose is to find the levers to push in order to create movement.

The experiment 'Slim&Snel' was designed with the intention of changing the procurement process as a lever for radical innovation. Housing associations approached the market with small scale projects through traditional procurement processes in which everything was prescribed in detail and in advance. Both builders and corporations experienced sustainable renovation as being difficult and expensive and at the same time knowledge of suppliers was not used and innovation had no chance.

Steppingstone 3 – Identifying allies

Steppingstone 3 is about the micro level of a transition initiative. You identify the specific operational context of the initiative with which you hope to achieve a transitional effect. This includes listing allies and critics and understanding power structures, relationships and the undercurrent.

We have worked in various cities on initiatives to create the urban conditions for net zero refurbishments. In the urban context the municipality and local government is an important factor and we meet very different situations. For example in Tilburg, the alderman in question had both public housing and sustainability in his portfolio and was able connect these policy field easily. In Amersfoort, the alderman was replaced shortly after the start of project and barely became involved. In Utrecht, two aldermen were involved. One was enthusiastic and one was a critical former member of the Dutch Parliament. He was skeptical about the role of housing associations, after a number of scandals in the sector in recent years.

Steppingstone 4 – System overview

The first three steppingstones are about exploring and enlisting interest. In stepping stone 4 this leads to a systems overview. All ingredients are essentially known, now it is time to connect them and identify points of leverage. Beware that these are dynamic! This steppingstone demands a highly developed sense of observation, interpretation and synthesis using your emotion, ratio and intuition.

Through 'Slim&Snel' the first NetZero energy refurbishment was developed. This experiment showed us which aspects would have to be adapted to scale up this concept. For example: changes in legislation, infrastructure, construction contracts and much more. Combining this with sectoral dynamics at that time and the interest of front runners to take it to the next level ultimately lead to De Stroomversnelling.

Steppingstone 5 – System overview

Process architecture is about choosing an approach to work towards the desired outcome or journey. Specific goals and context require different approaches. Sometimes it is necessary to diverge and be unfocused, othertimes it is necessary to converge and consolidate. Sometimes a small group is necessary, othertimes a wide array of people need to be involved. Which type of architecture do you plan in the context of the transition you are working on?

De Stroomversnelling is based on the idea of process architecture: make enough impact through scaling up the NetZero energy refurbishments and thereby create enough impact to justify and eliminate restrictive market conditions.

Steppingstone 6 – Determining interventions

Participating in a transition program with uncertain outcomes requires drive, belief and trust. It is about connecting elements that together make the difference. Constantly, we ask ourselves: what does this situation require? Who needs what? What does the process need? How will I deliver that? Where is the brilliance? Different answers might lead to different actions, such as creating more or less structure, inviting experts from outside the group or instead creating an intimate setting.

We define three types of interventions: Proces, Form and Content (see Figure 2 on the next page).

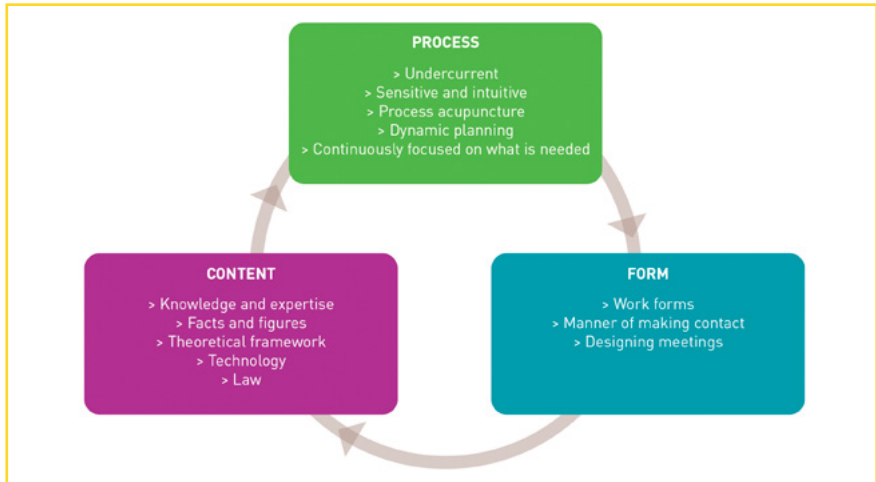


Figure 2: Types of interventions: process, form and content

An important issue in De Stroomversnelling involved the definition of the performance indicators the builders would guarantee for the refurbished houses. We wanted more than just energy performance, including things such as air quality, light admission and sound insulation. The builders, however, could not agree on a joint basis for key performance indicators (KPIs). There were fierce disagreements. To create movement on this front, we decided to hire an external expert to draft a document describing all the KPIs. This document received more than a 100 comments. We decided to address every one of them in a group setting. Instead of fundamental differences, we now only faced differences of detail. This intervention eventually led to a set of KPIs all participants agreed upon.

Steppingstone 7 – Space for new ideas and connections

Although we work from a specific goal and program, the actual transition cannot really be created or predicted. It is a result of complex system dynamics and involves *emergence*, i.e. comes into being as a result of all the new combinations that are made in the process, *co-evolution*, i.e. in continued adaptation to different parts of itself, and *self organisation*, i.e. spontaneous structuration. In the processes that we design we accommodate this. We make space for new ideas and new connections between ideas.

During the ‘Slim&Snel’ experiment we introduced the term ‘sparkles or brilliance’ to indicate that real new ideas were needed. Initially, there was a specified and detailed set of requirements that left no space to the consortia of suppliers. We

reduced that to the essentials. Then we built it up again using the unconventional and brilliant ideas of the builders.

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Steppingstone 8 – Self-perpetuation and system change

Transition initiatives are aimed at discovering and creating a new norm or practice. Projects, interventions and programs are often temporary. The last steppingstone is about this long term change, about self-perpetuation and system change. We identify three aspects:

- Permanently altering (market) conditions
- Creating new contexts and structures
- Changes in practice and beliefs

All Energiesprong initiatives are geared towards permanently changing the business as usual. For example by publishing lessons learned and best practices and by training trainers. New (temporary) structures and contexts are created by facilitating partnerships such as De Stroomversnelling of regional coalitions like the 'Brabantse Stroomversnelling'. Market conditions are improved by having the rental law changed.

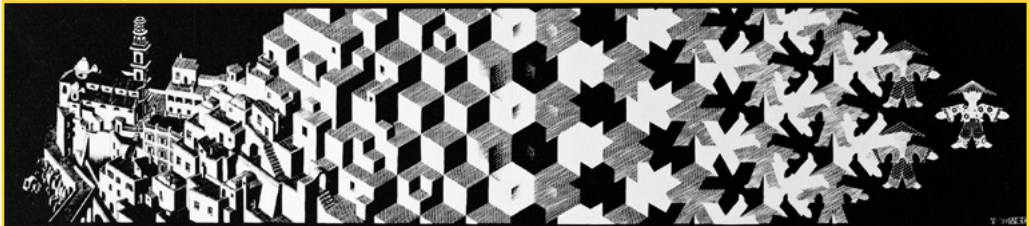


Figure 3: Escher *Metamorphosis II* – transforming from one system to another (licensed)

4 Different roles

We identified three roles to accelerate transition and put them into practice:

- The *process coach* facilitates a group of people while they are in a transition context and is explicitly tasked with keeping an eye on content, goal and strategy

- The *quartermaster* has a more initiating and organising role, foremostly gaining allies and commitment for a particular project or partnership
- The *monitor* is part of the team with process coaches and quartermasters and takes care of reflection on the process and impact, by gathering and sharing information from the process and environment

5 Conclusions

The steppingstones enable us to experience a structured way of purposefully operating in the practice of transitions, where the inherent uncertainty and the conflict between the old and the new would otherwise have left us reeling. Every process and every context is different. There are no shortcuts. Every time you have to search, learn, experiment, define, extrapolate and adapt. The steppingstones represent a practical approach to systems thinking.

The activities employed by Energiesprong have – as a side effect – contibrued to a new kind of profession, namely transition practice. The chaordic steppingstones and the different roles are part of this practice. The task for all is, ultimately, fundamental change towards a more sustainable society. That will inevitably lead to processes of change and transformation. Within you, within us, within others, and thereby, within systems.

The steppingstones and this paper are a work of practice, not theory. We recognise scientific limitations of this paper. We hope this publication will lead to constructive dialogue and strongly support further (scientific) research.

ACKNOWLEDGEMENTS

The concept of the steppingstones originates from the work of, amongst others, Chris Corrigan, Tim Merry and The Art of Hosting. We have been inspired by this work and have built on it to create these chaordic steppingstones for sustainable change in practice.

TITLE	AUTHOR	ORGANIZATION	MAIL ADDRESS
Chaordic Steppingstones on the Path to NetZero Energy	J.I. (José) van der Loop CO-AUTHOR Ir. Petra Hofman	JVDL Advies – Art of Transformation Amersfoort, the Netherlands Diep, www.diep.nl Apeldoorn, the Netherlands	jivanderloop@gmail.com tel. +31 6 14610716 petra@diep.nl

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PRINCIPLES AND PRACTICE OF ZERO ENERGY BUILDINGS IN ESTONIA

In Estonia the well-described regulation establishes the methods for calculating the energy performance of buildings to prove their compliance with the minimum requirements for energy performance. The definition of the nZEB and ZEB building and the methodology of the calculation of the energy performance of the buildings in Estonia is described. The problems and results of architectural design process performed by local government are described based on the case study of a newly planned nursery home. The study shows the influence of the different parts of the building components and building service systems (building components, building service systems, plug loads, etc.) on the balance of the energy consumption and utilization and on the energy performance of the building to achieve the ZEB building. Finally this article discusses the problems and limitations of the regulation influencing the motivation and actions needed to achieve the ZEB building.

1 Introduction

Europe has adopted an ambitious vision for the energy performance of its buildings: by the end of 2018, all new public buildings must be ‘nearly zero-energy buildings’ (nZEB). In the energy performance of buildings directive recast (EPBD 2010) nZEB buildings are defined as buildings with a very high energy performance and where nearly zero or a very low amount of energy need is covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. The directive requires nZEB, but it does not give minimum or maximum harmonized requirements. The limits and energy performance calculation framework for the nZEB buildings are set by the Member States.

The need to pay attention to energy performance of buildings in Estonia started with new regulations for the minimum requirements of the energy performance of buildings that came into effect in 2007. The regulation extends to new buildings and to existing buildings that undergo major renovation. The regulation is well described and has been updated concerning nZEB buildings (RT I, 24.01.2014, 7). The definition of the nZEB is given in the regulation and the regulation establishes minimum requirements for the energy performance of buildings, including low energy buildings, nearly-zero energy buildings and net zero energy buildings (ZEB).

There have been only few projects with good description of the design and constructing process and with following monitoring of the building in function that have aimed to achieve the nZEB in case of new buildings or renovation cases in Estonia. Raide (2015) has analysed the performance of the two different type of public buildings that were intended to be passive houses and addressed that there are new aspects that should be taken into account compared to the regular building design process.

The process starts with the design phase. Mistakes made in different stages of design phase can lead to unwanted results. One example is presented in this paper. In the case study case after all the design stages and supervision of the expert the questions for the owner arose about the implementation of the project. The questions were:

- Is it theoretically possible to achieve the nZEB building without the PV panels if the energy performance calculation is done using the standard use of the building according to the calculation methodology presented in regulations?
- Is it possible to achieve the ZEB building level if PV panels with nominal power of 100 kW are installed?
- Does the construction documentation show that the state of the art solutions are used in the design?
- Was the initial task too strict and not implementable?

This papers gives an overview of the regulation of the energy performance requirements, describes the calculation of energy performance of buildings and discusses the case study of the design process of a new building of a nursery school in Estonia.

2 Assessment of energy performance of buildings

In the Estonian regulation a nZEB building is a building that is characterized by sound engineering solutions, that is built according to the best possible construction practice, that employs solutions based on energy efficiency and renewable energy technologies and whose energy performance value is greater than 0 kWh/(m²·a) but does not exceed the limit value of 100 kWh/(m²·a). A ZEB building is a building whose energy performance value is 0 kWh/(m²·a).

The energy performance is proven in respect of the building as a whole. For the purposes of calculating the energy performance of the building, in addition to the envelope of the building and its utility systems, the local energy generation systems

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(such as solar collectors and panels, wind turbines, combined heat and power producers) which are located within the building or on the building site and which feed into the building are regarded as constituent elements of the building. Utility systems (such as district heating) which are connected to an energy network, up to the connection point to the energy network, are regarded as constituent elements of the building, see Figure 1 (RT I, 18.10.2012, 1).

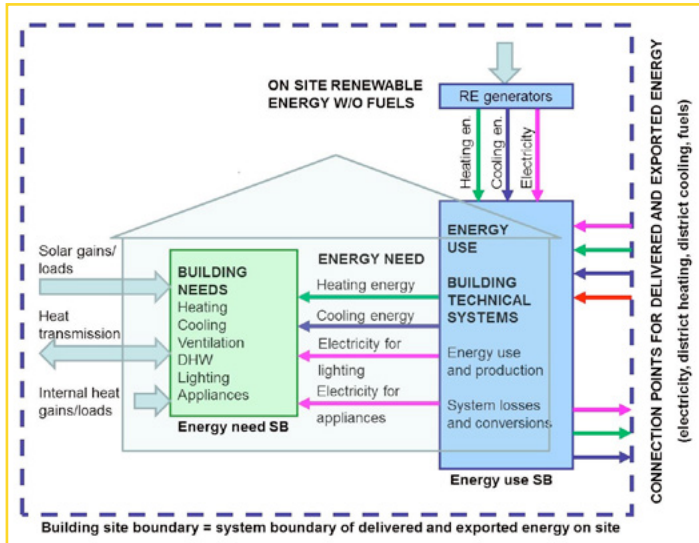


Figure 1: System boundary of delivered and exported energy

2.1 Calculation of energy performance of buildings in Estonia

The energy performance of buildings in Estonia is expressed as an annual primary energy (PE) usage and presented as the energy performance value (EPV, kWh/(m²·a)). The EPV includes the heat and fuel consumption for room heating, heating of ventilation and infiltration air, domestic hot water, and cooling as well, electricity for lighting, electrical appliances, and technical systems. The EPV is the total weighted specific use of delivered energy (DE) consumed in the course of standard use of the building.

The weighting factors for different energy carriers to calculate the EPV are:

- Fuels based on renewable energy sources (wood and wood-based fuels) 0.75
- District heating 0.9

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- Solid fossil fuels (gas, oil, coal) 1.0
- Peat and peat briquette 1.0
- Electricity 2.0

Energy calculation determines the building's aggregate energy use in relation to indoor climate control, the heating of the hot water and the operation of electrical equipment. The use of delivered energy, exported energy, and the EPV of the buildings are calculated on the basis of the result of the energy simulation. The energy simulations ought to be carried out with the validated dynamic simulation software.

Energy simulations are carried out in the course of standard use of the building. The standard use of buildings shows the building's occupied hours, and the maximum of the heat gains from appliances and lighting and from occupants during the building's occupied hours. The calculations are done taking into account the minimum indoor climate requirements presented in the regulation. In the energy simulations, regardless of the building's location, the Estonian test reference year (TRY) is used for outdoor climate in Estonia (Kalamees 2006). The information about the building is obtained from the building design documentation. The infiltration air flow rate is calculated using the base value of the air leakage rate presented in regulation.

3 Case study

The planning of the day care centre in Palamuse is described. As the building will be state owned the contracting authority is the local municipality. Usually the local municipality's building department or official will be responsible for the management of design and following construction works.

The net area of the building was planned for about 1,900 m². The building was designed for 5 groups with 104 children in total. The day-care facilities were located on the first floor. Technical room was located on the second floor.

The project started in 2014 with the architectural competition to find the architect and the draft design of the building to work on in the next steps. The call for architectural competition included also an energy efficiency part: the building has to fulfil the requirements for the nZEB building presented in energy efficiency regulations. Additionally, the designed solutions have to be cost-effective and the solutions have to ensure the passive house standards (maximum allowed energy demand for heating is 15 kWh/m²-a, the architecture must support the passive solar energy usage, the envelope must be without thermal bridges, the ventilation system must be with high heat recovery, and n50 must be <0.6 h⁻¹). Furthermore, it was stated that the nZEB

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level must be fulfilled without using PV panels. Moreover, if PV panels with nominal power of 100 kW are installed then the building must fulfil the ZEB building. Finally it was recommended to involve the energy efficiency consultant in the design process. Altogether 17 architectural proposals were submitted to architectural competition. The committee, consisting of local authorities and architects, was selected to evaluate the submitted works and to choose the best architectural solution. The winning design was chosen and there were no conflicts stated with the initial task. Also, the designer declared the initial task implementable.

After the contract, the design work was carried on through the next design stages. In Estonia there are three main design stages: preliminary, developed design and construction documentation.

The architect changed the energy efficiency consultant after the preliminary design. In the developed design stage the energy performance calculation was carried out. The calculations were done by the company who designed the HVAC systems of the building. Since the calculations in the first stage were too optimistic, the architect had to admit the mistake of the first calculations. After the developed design the architect proposed to lower the nZEB target level to low energy building level or change the initial task so that the PV panels will be installed without reaching the target level of ZEB building.

The design result was a building (Figure 2) with ground source heat pump and floor heating, ventilation with heat recovery and an airtight building ($q_{50}=0.8 \text{ m}^3/(\text{h}\cdot\text{m}^2)$) envelope with the specific heat loss coefficient of $0.34 \text{ (W/K}\cdot\text{m}^2)$. The calculation of energy performance showed the EPV of $115 \text{ kWh}/(\text{m}^2\cdot\text{a})$ without solar panels and EPV of $22 \text{ kWh}/(\text{m}^2\cdot\text{a})$ if the PV panels (with nominal power of 100 kW) and solar collectors (20 m^2 for hot water) are taken into account.

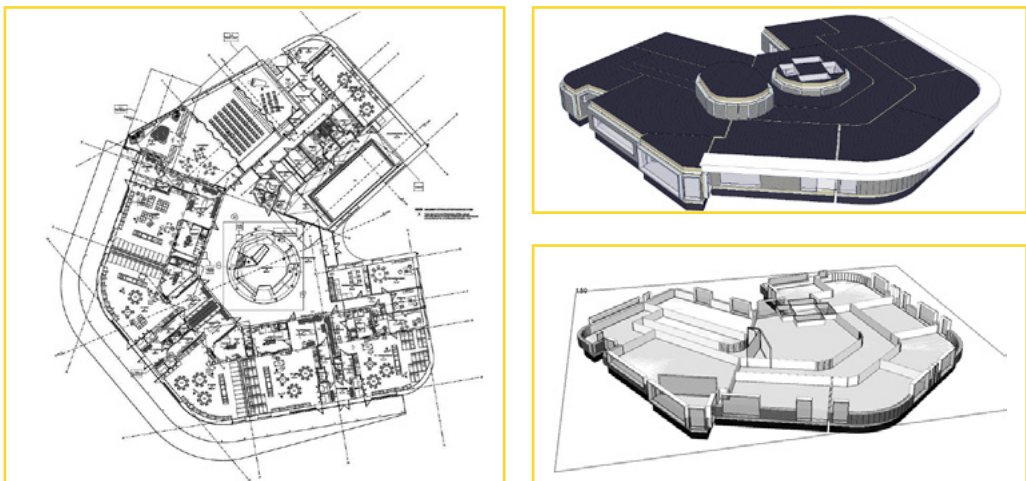


Figure 2: Floor plan and picture of the simulation model of the building

In case of the public procurement the common practice is that the final design will go through the supervision of the third party expert. The expert had no comments concerning energy efficiency or HVAC systems of the designed building.

After all the design stages and supervision of the expert the local municipality asked for an independent opinion. For the owner it was not clear if the initial task of the project was implementable or not. The inspection of the construction documentation and additional analyses of the energy performance of the building was carried out. Taking into account the finalized design and the possibilities for adjustments different simulation cases were analysed. To reach the nZEB level the corrections and adjustments that had to be done in the design are:

- Correct thermal transmittance and thermal bridges values (values were corrected based on the calculation results using the drawings of the construction types and construction's junctions from the architectural design)
- Heat gain and the energy use of electricity of the lighting presented in regulation is lowered from 15 W/m² to 10 W/m² according to illuminance calculations in rooms
- The SFP of the ventilation system has to be changed from 1.7 kW/(m³·s) to 1.5 kW/(m³·s)
- A ventilation system with variable air flow (VAV) has to be installed (a ventilation system is regulated according to the CO₂ level and room temperature)
- Change of window size, the original windows spanning from floor to be raised up 0.5 meters from floor and the upper level is left as in architectural design. Window height is reduced from 2.4 to 1.9 meters
- Airtightness of the building envelope cannot be higher than 0.8 m³/(h·m²), to ensure the airtightness the drawings in the construction documentation must be corrected and construction process must be described in detail

The calculation of energy performance showed the EPV of 94 kWh/(m²·a), with energy use of 100 MWh in total for year. The distribution of the energy losses and gained energy in the room of the final calculation is presented in Figure 3.

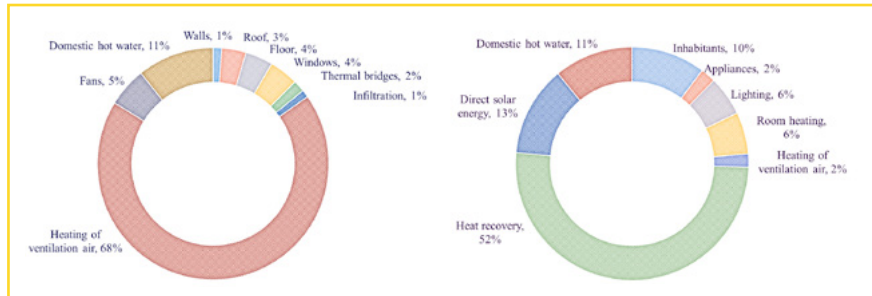


Figure 3: Distribution of energy losses and gained energy in the room

The question if the nZEB can be changed to ZEB in case the PV panels with nominal power of 100 kW are installed remained. Interactive map of photovoltaic geographical information system (PGIS) (<http://re.jrc.ec.europa.eu/pvgis/>) was used to estimate the performance of the grid-connected PV system. The building integrated PV panels, installation on the roof of the building, oriented to south with the installation angle of 38° were considered. The estimated total solar electricity generation with total losses of 23% for year would be 93 MWh.

4 Discussion

Architecture can have a significant impact on the energy efficiency of the building. Architects have a complicated task, in some cases the architectural design is dictated by the rational solutions required by ZEB buildings (Thalfeldt 2013). The importance of the airtightness and envelopes without thermal bridges or HVAC systems are underestimated, but play a very important role in case of the ZEB. The thinking of designers, constructors and supervisors must change. Compared to a traditional construction project, ZEB projects are more challenging because of the different aspects.

To design ZEB building, it needs more analyses in the early stage (Kantola 2015). Simple tools like (Kurnitski 2013) is needed. In the next design stages the energy simulations have to be carried out after different stages if more detailed data can be taken into account (Micono 2015). For example in regulations it is allowed to use lower wattage of the lighting if the illuminance calculations are presented with energy calculations or to use the VAV system. The HVAC systems of the building and the everyday usage of the building should be more thought-out before the energy calculations.

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In Estonia the commonly used procurement to choose the contractor is based on the lowest offered price in case of the state owned buildings, constructing a new or retrofitting existing building. This may lead to a situation where owner cannot choose the designer based on the designer's competence. In the case study public architectural competition was organised in order to avoid this situation. Selection was made based on the presented preliminary architectural design by the committee. The committee consisted representatives of the local municipality and architects. Unfortunately the committee of judges did not include any energy efficiency experts. In case of Estonia the small size of the market can be seen as a deficiency. Lack of experts makes it difficult to find qualified consultants for the supervision. It would be best if the supervising consultant was involved from the very beginning of the project before any other parties and follow-through. It helps to avoid the problems caused by the lack of experience or competence of the owner. First the expectations and needs of the owner have to be put straightforward to the contractor, afterwards observed and directed to the completion.

In Estonia the highest energy need in buildings is during the heating period. However, the possibility to use the solar energy is during the summer. The possibility to gain benefits from the solar energy requires the possibility to sell produced electricity to the grid in case of nZEB and ZEB buildings. Therefore the current electricity legislation limits the nominal power of PV panels to 100 kW in the case of local small scale electricity production by renewable sources.

4 Conclusions

The results of the additional energy simulation showed that the nZEB level is possible. The data of building envelope had to be corrected and adjustments in design documentation in accordance with regulation had to be done. Taking into account the higher energy performance demands the building process in construction documentation concerning energy performance must be described in a more detailed manner.

The initial task was not implementable in case of the ZEB requirement if the PV panels with nominal power of 100 kW would be installed. The result of the estimated total solar electricity production compared to total energy use of the building showed that ZEB level with nominal power of 100 kW PV panels is not achievable.

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Guidelines for all the phases of design and construction of a ZEB building are needed. The guidelines would make it possible for contract authorities to make first level supervision and prevent mistakes to achieve the designed ZEB buildings also in real life. Next step is to organise training and education for the responsible staff in municipalities. Further pilot projects as examples are needed. Additionally it is important to collect all the examples and make it public for motivation and for learning about the suitable solutions and how to avoid mistakes.

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THE CHALLENGE OF INTEGRATING 'ENVIRONMENT' INTO URBAN PLANNING

Sustainable urban development entails integration of environmental interests in decision making about urban plans. In practice, the results appear to be rather mixed. Adopting three different perspectives, five explanatory factors were identified that influence the extent to which integration is successful. These include the multidimensional and multiscalar nature of urban environmental quality itself and nature and institutionalization of the decision making process. The factors identified may serve as design requirements for modern planning support systems. Moreover, the more holistic view resulting from combining the three perspectives sheds a novel light on the complexity of integration. These insights benefit planning – and planning support.

1 Introduction

Today, over 50% of the world's population is living in cities. Therefore, sustainable development is a challenge of achieving sustainable urban development, i.e. the pursuit of urban space of high quality, without compromising the conditions for this process to continue (Fischer & Amekudzi, 2011; WCED, 1987). Any definition of sustainable development entails integration of economic, social and environmental interests (e.g. Campbell, 1996). In an urban development context, the latter are: use of space; substitution of open-ended flows by closed cycles; reduction of energy use and emissions; minimal use of hazardous materials and a healthy and green environment (Næss, 2001).

This is the rationale for developing compact, high-density, mixed-use inner-city urban areas. Here, different urban functions heavily compete for scarce urban space, in particular as their environmental impacts are often perceptible in a wider area, leading to conflicts between urban environmental quality (UEQ) and compactness (Bartelds & De Roo, 1995; De Roo, 2000; 2001).

These spatial-environmental conflicts further complicate the urban planning process which is complicated as it is: elements for the solution of the planning problem at hand are distributed among multiple actors, each active in multiple decision making arenas that only partly overlap and change composition over time. Within

these arena's, issues are continuously reframed (Teisman, 2000), also influenced by dynamic public and political agendas.

The central premise of this paper is that, within this multi-actor, multi-level setting, trade-offs among the multiplicity of interests at stake are likely to be made at the expense of UEQ (Miller & Wood, 2007). This is problematic, because, in western urbanized areas, large proportions of the population already are exposed to high levels of noise, air pollution and industrial risk, which may lead to health and safety risks (Ale, 2005; Beelen et al., 2014; Howley et al., 2009; Weber & Driessen, 2010). Theory about environmental policy integration offers a framework to understand why integration of environmental interests is – or is not – successful. This paper draws on previous research to identify five explanatory factors. It then reflects upon the meaning of these factors for planning practice, particularly planning support.

2 Analytical framework

Theoretically, three different analytical perspectives can be taken (see Fig. 1). These perspectives allow identification of five factors explaining the extent of integration of UEQ considerations into planning decisions.

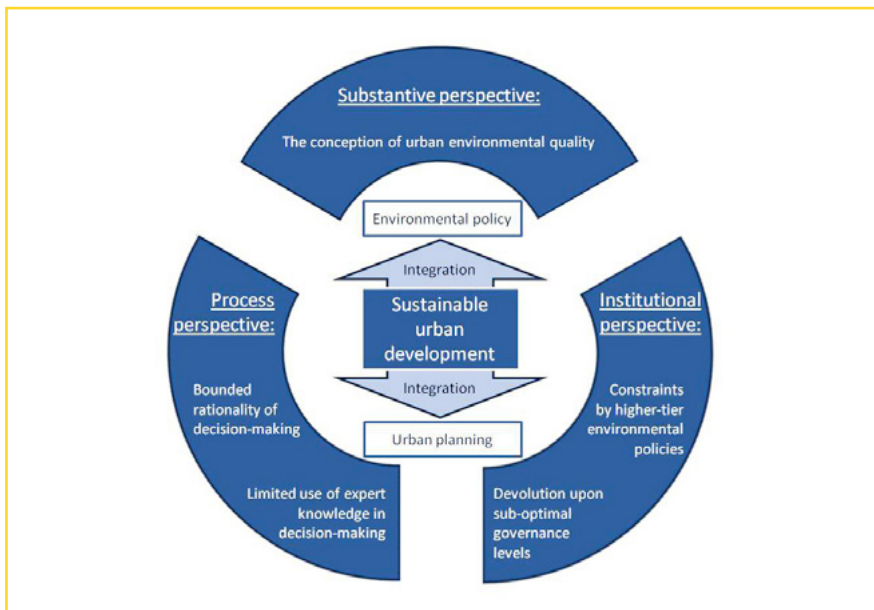


Figure 1: Three perspectives on sustainable urban development, through the lens of environmental policy integration

The first factor is the conception of UEQ in terms of 'what', 'for whom' and 'at what time' (van Stigt et al., submitted). The second is the bounded-rational character of decision making (van Stigt et al., 2013b). The third is the way in which expert knowledge about environmental impacts is used within the urban planning process (van Stigt et al., 2015). From the institutional perspective, a fourth factor is restriction of local authorities by policies of higher government tiers (van Stigt et al., 2013a). The fifth factor is the way in which devolution upon lower government tiers is shaped in order to allow them sufficient room for manoeuvre, while still maintaining environmental quality standards (van Stigt et al., 2016). These factors are intricately connected. In concert, these five factors complicate integration of environmental interests.

3 The complexity of integrating 'environment' in urban planning

3.1 Urban environmental quality is complex in itself

Achieving sustainable urban development is often thought of as balancing three types of goals: economic growth, social equity and environmental protection (e.g. Campbell, 1996)^{*}. In this model, the planner's role is to 'manage and resolve conflict and to promote creative technical, architectural, and institutional solutions' (Campbell, 1996, p. 305). This model is too simple. In fact, what is pictured as a single environmental interest appears to consist of multiple quality dimensions. Each of those must not only be balanced with social and economic interests but also among each other.

In addition, then, to integrating UEQ into urban planning, there appears to be a need for integrating the elements that constitute it. These individual factors are related to different kinds of needs of the people involved, i.e. the residents and users of the space concerned. Therefore, they have subjective as well as objective determinants. Furthermore, people's needs and preferences change across time.

Successful integration of UEQ in urban planning is, therefore, not only a matter of the extent to which environmental quality is being considered in the planning process, but also of precisely which UEQ factors have been considered, by whom and at what time.

3.2 Scale issues add to the complexity

Second, UEQ is multiscalar. A single activity, like a planned compact inner-city redevelopment, typically influences – and is itself influenced by – bio-geochemical and social processes at multiple spatial scales. (Cumming et al., 2006). These range from global, in the case of climate change, to local, in that of noise. Successful integration would have to account for all of these processes and the policies implemented to

^{*} A more stringent view is that sustainable development entails giving 'principled priority' to environmental interests (Lafferty & Hovden, 2003)

steer them. This, however, is beyond the scope of local decision makers. In fact, governing these processes takes place at the corresponding administrative level (Cash et al., 2006). Therefore, coordination of policies and ensuing activities is necessary (Termeer et al., 2010). In decentralized states, coordination is guided by the subsidiarity principle: higher tiers of government decide about those issues that, according to the spatial scale level involved, fall within their remit, thereby setting restrictions with respect to those issues for lower administrative levels, thus limiting municipalities' room for manoeuvre in setting locally balanced targets for UEQ (van Stigt et al., 2013a). Thus, in environmentally highly burdened areas the allocation of competences among levels of government may paralyse local decision making. As an alternative, then, the authority to set UEQ objectives could be completely devolved upon the municipal level, in combination with an area-specific perspective and stakeholder participation (Simeonova & van der Valk, 2009; Weber & Driessen, 2010).

Incorporation of 'new' (i.e. to the municipality's remit) objectives, however, is value-laden (e.g. Holden, 2012; Richardson, 2005). Thus, local sectoral interests can easily be prioritized over weaker interests, such as environmental quality (Runhaar et al., 2014), or over interests that are beyond the scope of local decision makers, such as climate change.

Steering multiscalar processes entails inclusion of – government and non-government – actors involved in governing these processes. Obviously, this enhances the complexity of the decision making network, adding actors or even decision making arenas. Novel opportunities to connect or reframe issues may appear. The success of integration then depends on the planners' ability to create windows of opportunity in these changing circumstances (van Stigt et al., 2013b).

Taking all of these processes into account in decision making involves expert knowledge about the effects on UEQ, about possible measures to address these effects and about the policy instruments to implement these measures. Municipal politicians were found to decide about urban plans more or less intuitively, balancing all interests in order to have optimal political and public support for the ensuing plan, rather than looking for the best possible environmental quality (van Stigt et al., 2015). It is likely that UEQ aspects outside the local scope bear less weight in decision making, unless administrative approval from higher government tiers is obligatory.

Thus, the five explanatory factors are closely intertwined. In the next section, we will see what this means for planning practice.

4 Implications for planning and planning support

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4.1 Participative planning at multiple spatial and administrative scale levels

Successful integration of urban environmental quality requires a modus operandi that is congruent when adopting all three perspectives. A flexible approach to sustainable urban development allows municipalities to deviate from centrally issued environmental quality standards, striking a local balance among multiple quality aspects. This amounts to an institutional change. An obvious issue seen from the process perspective then, is how the decision making process will be designed and what actors – at what relevant levels – will be included in each stage of the planning process. This requires a careful design of the network of decision making arenas. A community-based planning approach is in order (e.g. Fahy & Cinnéide, 2006; Warner, 2002), allowing for participation of and interaction among stakeholders. This, in turn, is important for the creation of 'decision windows' (Nilsson & Dalkmann, 2009), by facilitating stakeholders to jointly reframe the issues related to urban environmental quality (Teisman, 2000; van Bueren et al, 2003). Furthermore, 'decision windows' can be created by actively connecting issues at various spatial and administrative scale levels through the agency of a policy entrepreneur (cf. Kingdon, 1995). In addition, within each of these arenas, policy entrepreneurs must be present who are able to connect issues – often at distinct spatial and administrative scales.

A community-based approach may also help in bridging the science-policy divide (McNie, 2007; Yearley, 2006). However, it is obvious that interests that are impacted at higher spatial scales must also be taken on board, e.g. by including representatives of these higher-level interests (see also: Bradshaw, 2003; Newig & Fritsch, 2009). Planning will therefore continuously move back and forth from one spatial scale level to another. Planning support must include knowledge about relevant processes at these multiple spatial scales that pertains to UEQ.

From the process perspective, political support is also important. The aim is to increase the relative weight of the environmental quality relative to other interests. Here, too, a policy entrepreneur may connect urban environmental quality to other issues that are prominently on the public agenda. However, win-win only goes so far. At some stage, difficult trade-offs are necessary. Local politicians may be inclined to avoid these, since they are dependent upon the voters' favour in local elections.

4.2 Planning support to deal with qualitative multiplicity

Local authorities, especially smaller ones, are likely to need some guidance as to how to optimally deal with the complex issue of urban environmental quality. Such guidance could cover operationalisation of subjective urban environmental quality indicators, making trade-offs among quality dimensions and balancing short-term and long-term interests on all relevant spatial scale levels.

Particularly, guidance tools are required that help manage the qualitative multiplicity

of sustainable urban development. An obvious tool is an urban environmental quality proxy, like a typology of urban qualities that are specific for a certain type of area. These area types each have different urban environmental quality targets, assigned by experts. A target is a comprehensive set of urban environmental quality indicators, the reference values of which can differ according to the sensitivity of the area and the type of activities planned to take place in it. Intensively used mixed-function city centres, for example, can have higher levels of noise and air pollution compared to much quieter, greener and cleaner residential areas. In the Netherlands, some municipalities have used such methods (Runhaar et al., 2009; Simeonova & Van der Valk, 2010; VNG & IPO, 2004). Reference values can have a certain band width, the lower level of which is equal to the (supra)national or provincial standard for a particular dimension of urban environmental quality, if any is in effect. The upper level is an ambition, i.e. a value that is ideally reached in a certain type of area, to be characterised by the occurrence, intensity and spatial vicinity of intrusive and sensitive functions. In this way, decision making about the urban plan can focus on urban environmental quality ambitions that are well above minimum standards. As these quality profiles have a spatial component, the use of GIS-based methods can help to see how planning choices influence urban environmental quality (Pelzer et al., 2013), provided they are set up in co-design with the prospected users (Te Brömmelstroet & Schrijnen, 2010).

4.3 A smart 3D planning support tool

In order to provide data for the analysis of UEQ that are available for all actors involved, the research group Supply Chain Redesign in the Built Environment of the Utrecht University of Applied Sciences, proposes a smart 3D city model that has four functions:

- Communication. A 3D view of the city is essential when working with various parties, with different levels of map reading skills, a 3D
- Data storage. All available data of a specific location are stored in that specific location
- Research. Spatial analysis functions are added to the city model, e.g. calculation of noise level contours or CO2 emissions
- Planning support. This is an accumulation of the three previous tools

Such a model could help deal with the complexities highlighted above. First, it provides some 'common ground' to stakeholders with very different backgrounds,

both professionals and lay persons involved, some of whom will prefer seeing a 3D model – and data projected in it – over a much more abstract 2D map with separate tables containing these data. Second, the same model and data can be used in multiple decision making arenas, highlighting only those 'views' on the data that are of interest to a particular constellation of actors. These different 'views' include relations of the local redevelopment project with processes at higher spatial scale levels. Third, it can be used to better inform local decision making, precisely because it can offer many different perspectives and, therefore, a more holistic perspective. This is particularly important if local government is given the authority to set UEQ objectives, rather than conforming to standards issued by higher levels of the state. Alternatively, the model could be used to compare the effects on UEQ of different scenarios in which local governments negotiate or enforce conformity with such standards.

More details on the function of the smart 3D city model and its applications, can be found in the paper by Heere et al. as part of the SBE16-Transition Zero conference. In designing the model, the above mentioned factors that complicate integration of UEQ in urban planning will be used as boundary conditions.

5 Conclusions

The holistic perspective taken over the course of our research adds three important insights to the existing literature. First, it reveals the qualitative multiplicity of sustainable urban development in terms of urban environmental quality aspects and related spatial and administrative scale levels. Second, building on diverse bodies of literature, it identifies five factors that explain why integration of environmental quality aspects in urban planning is sometimes problematic. These five factors act in concert, making it impossible to address one of them without also influencing at least some of the other factors. And third, adopting a normative approach, it nuances the call for flexibility in dealing with environmental quality standards.

Whether or not to devolve authority to set urban environmental quality objectives is a matter of political choice. In complex cases of compact inner-city redevelopment, rigid environmental quality standards are sometimes found to be too restrictive for urban planning. Devolution can then be a useful approach if the quality aspects that 'matter' – in the sense that they are close to or over some legal limit – involve mainly local processes. If, however, local urban development involves higher-level spatial scales, devolution expectedly leads to insufficient attention to those quality aspects or to coordination problems between the local administrative level and the appropriate higher ones. Thus, planning compact, inner-city development calls for participative planning, in which, because of the multiscale issues, all relevant scale levels must be taken on board. Smart 3D models and GIS analysis appear well suited to support the planning process, provided they meet these requirements.

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TITLE
**The challenge of
integrating 'environment'
into urban planning**

AUTHORS
Rien van Stigt MSc
Dr Elger Heere

ORGANIZATION
**Utrecht University
of Applied Sciences**
Utrecht, the Netherlands

MAIL ADDRESS
rien.vanstigt@hu.nl
tel. +31 6 38150420
elger.heere@hu.nl

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VOLUNTARY PROGRAMS FOR LOW-CARBON CITIES: A GOVERNANCE INNOVATION THAT IS TOO GOOD TO BE TRUE?

Seeking to overcome shortfalls with statutory regulation in the transition to low-carbon cities governments and non-governmental actors have begun to experiment with voluntary programs. This paper presents a summary of a four year research project into 60+ voluntary programs for sustainable building and city development and transformation from Australia, India, Malaysia, the Netherlands, Singapore, and the United States. It finds that not too much should be expected from voluntary programs, and argues for hybrid governance interventions – that combine aspects of mandatory and voluntary programs – as a way forward.

1 Introduction

Voluntary programs have become increasingly popular in the transition towards a low-carbon economy. They are particularly dominant in the area of low-carbon building and city development and transformation. These programs typically challenge their participants to improve the resource consumption and carbon emissions of their buildings well beyond what is required by statutory legislation.

This paper presents a summary of a four year research project into 60+ voluntary programs for sustainable building and city development and transformation from Australia, India, Malaysia, the Netherlands, Singapore, and the United States. The project was funded through a VENI grant from the Dutch Organisation for Scientific Research (NWO). Due to space limitations an in-depth discussion of all programs cannot be provided – see www.jeroenvanderheijden.net/research_current_VENI.html for the full set.

2 Why a move to voluntary programs

Voluntary programs respond to some of the key problems that mandatory regulation and legislation face in accelerating the transition to a low-carbon built environment. These are, first, new regulation can often not keep up with technological innovations.

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Second, new and amended regulation often exempts existing buildings and infrastructure from compliance – through so called grandfathering clauses. Third, mandatory regulation requires considerable institutional capital to implement and enforce. Fourth, traditionally building regulation and legislation addresses objects and not behavior. User behavior is, however, key in reduced building and city related resource consumption and carbon emissions (see further Van der Heijden, 2014).

Traditional regulation and legislation builds on a model of mandatory and enforced compliance. Voluntary programs seek, on the other hand, to achieve environmentally sustainable building development and use through compliance through positive incentives. These include the ability to brand buildings as more environmentally sustainable than those of competitors, or to get access to funds that are earmarked for innovative building development. Because of these positive incentives voluntary programs are expected to yield better results than traditional mandatory regulation (Potoski & Prakash, 2009).

An alternative application of voluntary programs is to trial and test novel technologies and prototypes. This paper is not concerned with this application of voluntary programs.

3 Examples of the voluntary programs studied

- *Certification and classification:* These voluntary programs are built on a simple and elegant design. They allow for the assessment of a building's environmental sustainability and other credentials against a set of criteria. Normally these criteria move well beyond mandatory building regulation and construction codes. Upon assessment a certificate is awarded indicating how well the building performs in complying with those criteria

A building certificate fulfils an important function in bridging low-carbon building supply and demand. The certificates give consumers of these buildings certainty that their building meets specific criteria. And they give suppliers a means to distinguish their buildings from those of their competitors (see further Van der Heijden, 2015a). A typical example is Leadership in Energy and Environmental Design (LEED)

- *Information generation and sharing:* These programs seek to generate knowledge on how to achieve and use low-carbon buildings; they all require participants to share their experiences in this area with others; and often

program administrators (mainly governments) act as “knowledge brokers” in transforming these experiences to transferable knowledge. They often do so by documenting these experiences as case studies and best practices on publicly available websites (see further Van der Heijden, forthcoming)

A typical example of this type of programs is the Better Building Partnership in Sydney. This is a collaboration of the City of Sydney Government and the city’s 14 major property owners. Together these property owners own more than 50 per cent of all property in Sydney’s central business district. Through the program the City and the property owners seek to reduce building related carbon emissions in 2030 by 70 per cent as of 2006 emissions. They work together to generate and make available knowledge on achieving this goal

- *Innovative forms of financing:* These programs address the difficulty experienced by property developers and owners sourcing funds for developing or retro-fitting low-carbon buildings. A key problem here is that banks and other financial institutions are still hesitant to provide loans and mortgages for low-carbon buildings. They fear that the low-carbon credentials of these buildings are not reflected in their market value, which implies a risk if building owners cannot pay back the loans and mortgages provided (see further Van der Heijden, 2014)

A typical example is the Amsterdam Climate and Energy Fund. This is a so called ‘revolving loan’ fund that seeks to support the development of low-carbon buildings and other city development projects. The fund is revolving in that money is lend to property developers or owners. Once it is recouped from them it is lend again to others.

4 Overall program performance

The research project is interested in three specific program outcomes: (i) their ability to incentivize participation and attract participants; (ii) their ability to improve their behavior in terms of low-carbon buildings constructed or retrofitted, or improved building use performance; and (iii) their relative performance when contrasted with the behavior of the full pool of prospective participants. Table 1 gives a summary of the performance of a (representative) sample of the programs studied.

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Name (type, location and year of introduction)	Participating rule-takers relative to pool of prospective rule-takers	Average reductions by rule-takers	Reductions in perspective
BREEAM-NL (certification, the Netherlands, 2009)	45 per cent (of future commercial buildings)	Over 20 per cent (but paper performance [*])	Possible meaningful contribution, but risk that buildings do not perform as certified once built
Energy Star for Homes (certification, United States, 1999)	7 per cent	Over 20 per cent (but paper performance [*])	Approximately 1.5 per cent of commercial building energy consumption in the United States
EnviroDevelopment (certification, Australia, 2006)	6 per cent (of new residential buildings)	Over 20 per cent	Approximately 1 per cent of residential building energy consumption in Australia
Green Star (certification, Australia, 2003)	18 per cent (of new office buildings)	Over 20 per cent (but paper performance [*])	Approximately 4 per cent of office building energy consumption in Australia
LEED (certification, United States, 2000)	3 per cent (of new office buildings)	Over 20 per cent (but paper performance [*])	Approximately 0.5 per cent of commercial building energy consumption in the United States
NABERS (certification, Australia, 1998)	77 per cent.	Over 20 per cent	Approximately 15 per cent of office building energy consumption in Australia

Table 1 (1-4): Performance of a sample of the programs studied (clustered by type)

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Name (type, location and year of introduction)	Participating rule-takers relative to pool of prospective rule-takers	Average reductions by rule-takers	Reductions in perspective
Better Buildings Challenge (information, United States, 2011)	Less than 1 per cent (representing 4 per cent of commercial building space)	2 per cent (with a quarter of participant having achieved at least 10 per cent)	Less than 0.5 per cent of commercial building energy consumption in the United States
Better Buildings Partnership (information, Sydney, Australia, 2011)	100 per cent (all 14 initially targeted rule-takers)	35 per cent (on track to reach 70 per cent by 2020)	Applies to Sydney's central business district only. The larger Sydney Metropolitan area is 500 times larger
Chicago Green Office Challenge (information, Chicago, United States, 2008)	Less than 1 per cent	Less than 10 per cent	Futile compared to Chicago's commercial building energy consumption
CitySwitch Green Office (information, Australia, 2010))	6 per cent	13-16 per cent	Less than 1 per cent of office building energy consumption in Australia in 2011
Retrofit Chicago (information, Chicago, United States, 2012)	Over 5 per cent (of major office buildings)	7 per cent	Approximately 1.5 per cent of Chicago's office building energy consumption
1200 Buildings (financing, Melbourne, Australia, 2010)	4 per cent	Unknown (too few buildings retrofitted yet)	Futile† compared to Melbourne's commercial building energy consumption

Table 1 (2-4): Performance of a sample of the programs studied (clustered by type)

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Name (type, location and year of introduction)	Participating rule-takers relative to pool of prospective rule-takers	Average reductions by rule-takers	Reductions in perspective
Additional credit for energy efficient homes (financing, the Netherlands, 2012)	Less than 1 per cent	Unknown (too few houses constructed or retrofitted)	Futile compared to the Netherlands residential building energy consumption
Amsterdam Investment Fund (financing, Amsterdam, the Netherlands, 2011)	Less than 5 per cent (a handful of projects are funded)	Unknown (too few buildings retrofitted yet)	Marginal contribution to the City of Amsterdam's ambition of 20 per cent carbon reductions by 2020
Billion Dollar Green Challenge (financing, United States, 2011)	1 per cent	Over 20 per cent.	Futile compared to the energy consumption of educational facilities in the United States
Building Innovation Fund (financing, Adelaide, Australia, 2008)	Less than 2 per cent ^{***}	Over 20 per cent	Futile compared to Adelaide's commercial building energy consumption
E+ Green Building (financing, Boston, United States, 2011)	Less than 2 per cent ^{***}	Over 20 per cent	Futile compared to Boston's residential building energy consumption
Energy Efficient Mortgage (financing, United States, 1995)	Less than 1 per cent	Unknown (no data available)	Futile compared to residential building energy consumption in the United States

Table 1 (3-4): Performance of a sample of the programs studied (clustered by type)

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Name (type, location and year of introduction)	Participating rule-takers relative to pool of prospective rule-takers	Average reductions by rule-takers	Reductions in perspective
Energy Star Building (financing, United States, 1999)	3 per cent	Over 20 per cent (but paper performance [*])	Less than 1 per cent of residential building energy consumption in the United States
Environmental Upgrade Agreements (financing, Sydney, Australia, 2011)	Less than 1 per cent	Unknown (too few buildings retrofitted yet)	Futile compared to commercial building energy consumption in the state of New South Wales
PACE (financing, United States, 2008)	Less than 1 per cent (of commercial property)	62 per cent	Futile compared to commercial building energy consumption in the United States
Small Business Improvement Fund (financing, Chicago, United States, 2000)	Less than 5 per cent	Less than 20 per cent	Futile compared to Chicago's commercial building energy consumption
Sustainable Development Grant (financing, Brisbane, Australia, 2007)	Less than 2 per cent ^{**}	Over 20 per cent	Futile compared to Brisbane's commercial building energy consumption

Table 1 (4-4): Performance of a sample of the programs studied (clustered by type)

^{*} The term 'paper performance' indicates that these are expected reductions, not observed reductions; for example, most certification and classification programs studied have issued certificates for the design of a building and not the performance of a building in operation (see Chapter 4)

^{**} The number of rule-takers as part of possible participants applying for funds or participating in the competition

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- † The qualitative descriptor 'futile' indicates a maximum of 0.5 per cent.
Abbreviations: BREEAM-NL=Dutch application of BRE Environmental Assessment Method; LEED=Leadership in Energy and Environmental Design; NABERS=National Australian Built Environment Rating System; PACE=Property Assessed Clean Energy

A brief glance at Table 1 indicates that the voluntary programs studied have not achieved sweeping results. The programs have thus far not been able to attract a large percentage of the participants they target. They have not been able to considerably improve the carbon intensities and resource consumptions of their buildings. And they have not made a major contribution to the overall resource consumption and carbon emission reductions of the full built environment they target.

A word of caution is in place here. A close look at Table 1 indicates that certification and classification programs appear to perform, overall, slightly better than information generation and sharing programs, and novel forms of financing. This (more) "positive" performance should be considered in the light of the design of these programs. Certification and classification programs tend to assess the design of buildings or buildings once constructed. These assessments do, often, not represent the true resource consumption and carbon emissions of these buildings when in use. A range of studies into this type of programs has indicated that more often than not certified buildings once in use do not perform according to their certified design or construction (see further Van der Heijden, 2015a).

4 What explains this poor voluntary program performance?

Three key causes explain this poor performance (for a more extensive discussion see Van der Heijden, 2015a; 2015b; 2016):

- *Lenient rules and poor enforcement:* The majority of the programs studied set relatively lenient rules to their (prospective) participants. Hardly any of the programs studied requires resource efficiencies or carbon emission reductions of at least 20% beyond what is required by mandatory regulation and legislation. Whilst such efficiencies are often claimed to be easily achievable with well trialed technology and behavioral interventions, the results of the voluntary programs studied here indicates that particularly process barriers and disinterest at builder, owner, and user level stand in the way for seeing them achieved (see further Van der Heijden, 2014). In addition, many programs have very lenient enforcement regimes in place – if any. As such deviant behavior of participants often goes unnoticed by program administrators

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Program administrators have, however, a strong incentive to set low participation requirements and have in place lenient enforcement regimes. Strict rules and enforcement likely are negative incentives for prospective participants (it makes the program difficult for them). Program administrators have a strong interest in seeing large numbers of participants. Those administering certification and classification programs make considerable profit from doing so, and those administering information and funding programs will see their reputation improve with a large participant base. Thus, it is in the interest of program administrators to keep rules lenient and enforcement soft

- Dominant focus on industry leaders:* Generally, the programs have a strong focus on seeking to attract the absolute top-leaders in the industry. The assumption is that once these leaders are on board, others will follow. What the programs, generally, do not seem to grasp is that the construction and property sectors (the sectors they target for participants) are very heterogeneous. The leading practice of Sydney's 14 major property owners in the Better Building Partnership is unlikely inspirational for the average Sydney office owner. The 14 property owners together manage property with a value of over A\$1 billion; that gives them much more (financial) room to be leaders than the average office owner who has at best a few million in assets. They also have much more staff they can dedicate to researching and managing building upgrades than the average (individual) office owner
- The illusion of eco-efficiency:* Most programs built on the now dominant win-win narrative that underlies the green growth and ecological modernization paradigms – the idea that improved urban sustainability and economic growth (or at least economic prosperity) go hand in hand. The win-win promise does often not materialize in real world projects resulting from voluntary programs (or at least not on short terms), which convinces prospective participants that sustainable buildings are more costly and complex to construct than conventional ones. This then is a motivation for them to not participate

5 Conclusions

Whilst voluntary programs have, in theory, much potential for accelerating the transition to low-carbon cities, their real world implementation comes with a range of structural problems that stand in the way of achieving these goals. They have resulted in a wide range of good practices, but overall their impact is limited. A way forward may be to combine aspects of mandatory and voluntary programs in hybrid governance interventions. One could think of voluntary opting out programs

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176 (instead of the dominant voluntary opting in approach), of programs that mandate participation but leave the level of performance voluntary (as NABERS in Australia does), or programs that are voluntary for a fixed period and become mandatory afterwards.

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THEME 3 SMALL URBAN AREA: ENERGY OPTIMIZING SYSTEMS, 0-IMPACT AREAS RELATED TO ENERGY, WATER & MATERIALS, PARTICIPATION OF INHABITANTS AND QUALITY OF LIFE



Small urban areas are used as living labs or development zones to introduce energy refurbishment (products, services and models) that simultaneously meet social needs effectively on a small scale. Alternatives and new social relationships or collaborations are created in this areas. In other words, they are seeding ground for innovations which are both good for society and enhance society's capacity to act. Systemic change is the ultimate goal of NetZero Energy in small urban areas. This session will look at good practice and successful case studies of energy refurbishment and social innovation in action in small urban areas.

- a. Energy optimisation on urban area level
- b. 0-impact built environment: energy, materials & water
- c. Acceptance and participation of tenants of social housing projects
- d. Impact of low energy refurbishment on the quality of life in small urban areas

OPEN-SOURCE DEVELOPING, DESIGNING AND CONSTRUCTING SMALL URBAN AREAS WITH REUSED DEMOLITION WASTE IN THE CITY OF UTRECHT

The research group Supply Chain Redesign in the Built Environment of HU University of Applied Sciences is working on research that combines principles of the circular economy with open source architectural design & urban planning. The aim is finding new ways to reuse demolition waste and recycled materials in small scale urban area developments. And to “democratize” traditional processes in the built environment. Different recent studies have shown the potential benefits, such as a reduction of emissions. In “Hof van Cartesius”, a practical case study in Utrecht, the ambitions and implications of this approach are being questioned, investigated and tested.

1 Introduction

The research group Supply Chain Redesign in the Built Environment of HU University of Applied Sciences is working on research that combines principles of the circular economy with open source architectural design & urban planning. The aim is finding new ways to reuse demolition waste and recycled materials in small scale urban area developments. And to “democratize” traditional processes in the built environment. Different recent studies have shown the potential benefits, such as a reduction of emissions. In “Hof van Cartesius”, a practical case study in Utrecht, the ambitions and implications of this approach are being questioned, investigated and tested.

2 Open source architecture

2.1 Democratize production

In his paper “An Open-Source Building System with Digitally Fabricated Components”, Pieter Stoutjesdijk (2013) describes recent developments in both production technologies and communication technology that, according to specialists in the field, will initiate the next industrial revolution.

Developments such as 3D-printing enables “the larger public” to make, adjust, assemble and use their own products. The information, knowledge and “blueprints” needed to do so, are being accessed, shared and developed in online communities and collectives.

In theory, everybody from a single inhabitant to large-scale companies and institutions can now be engaged in designing, producing and assembling smaller or larger built structures.

Stoutjesdijk (2013) states that whereas the first industrial revolution democratized consumption, it can be expected that the next will “democratize production – through digital networks of shared knowledge and digital fabrication devices”. These statements originate, amongst others, from publications on the so-called “Maker Movement” (Anderson, 2012) and the theories of Jeremy Rifkin about the third industrial revolution and collaborative commons (Smith, 2014).

2.2 Open source in the built environment

In the article “Open Source Architecture: An Exploration of Source Code and Access in Architectural Design”, Vardouli and Buechley (2014) state that in translating the term open source from the domain of ICT to the built environment and architecture, the term is susceptible to different interpretations and uses. Even misuse. This gives rise to the question “what is open source architecture”? Or: “what should it be?”. It is clear that there is no unequivocal, indisputable definition of such a thing as “open source architecture”. In practice, the term is often used in situations where different stakeholders are invited to participate or collaborate more intensively than one is used to in traditional cases. Or where there is a need for openness and sharing.

Vardouli and Buechley (2014) question themselves what the equivalent of open source code in ICT is for the domain of the Built Environment. Is this all the information needed to erect a building? In other words, the digital drawings, technical details, planning, calculations and so on? If this is the case, BIM (Building Information Modeling), which has gained ground in recent years, will contribute to open source architecture without doubt.

For the research described in this paper, the authors will use the following self-defined, preliminary definition of the term “open source” in the built environment: The whole of the free accessible/adjustable, digital infrastructure (e.g. platform) and its protocols, as well as the technical data (e.g. drawings) of building methods, that enable everyone, in collaboration, to self-develop, -design, -produce and -construct built structures with limited professional knowledge and means.

Aside from the question what open source architecture means exactly, the question remains: can an open source approach to designing and building our built environment revolutionize the way we build? And will it cause the (dramatic) change in traditional (construction) industry as predicted?

The preliminary definition of “open source” as described above will be applied and tested, amongst others, in the case study “Hof van Cartesius” described below. In future, these and other studies must demonstrate whether or not the definition is justifiable. It must also prove whether or not “open source” is the next promising era in architecture and urban planning, that will accelerate innovation in the built environment or just an empty promise.

2.3 An example: Wikihouse

Examples or case studies of open source initiatives in the built environment are not widely spread (yet). Probably the most well-known and promising example at the moment is Wikihouse (see picture 1).

Wikihouse is an initiative by Alistair Parvin of Architecture 00 in London. In the article “Architecture (and the other 99%): Open-Source Architecture and Design Commons”, Parvin (2013) presents Wikihouse as a new model of open-source practice.



Figure 1: Example of a Wikihouse-structure: WikiHouseNL pavilion at the Meelfabriek-area in Leiden, Dag van de Architectuur 2014. Photograph by Jan Willem de Groot

Wikihouse is an open-source construction system. The idea is that everyone should be able to access the designs and knowledge of Wikihouse worldwide and customize, print and assemble structures by themselves. The materials used are widely available materials like plywood (18 mm thickness). The building parts can be digitally produced with a CNC machine. Assembling can be done with basic do-it-yourself (DIY) tools.

Newly gained experiences and knowledge is shared within the so-called “creative commons”, ensuring the constant development and progressing of the body of knowledge.

Alastair Parvin not only shared his thoughts on Wikihouse through the article mentioned above, but also in a TED-talk. Since then, the Wikihouse movement grew with the foundation of different “Wikihouse chapters” worldwide. Also in the Netherlands, a Dutch chapter of Wikihouse: WikihouseNL was founded. At this moment, six students of HU are working on the preparations for an Utrecht-chapter, in co-operation with WikihouseNL. The authors of this paper have initiated this Utrecht-initiative. The goal is to gain insight in the possibilities and limitations Wikihouse has to offer. And to find answers to research questions concerning the phenomenon of open source architecture.

One of these questions links both topics of this paper: what other materials than the standard 18 mm plywood can be used within the Wikihouse concept? Especially those, gained from demolition waste from within the city of Utrecht and thus, amongst others, reducing emissions (transition zero).

What (small-scale) applications can these Wikihouse structures made of demolition waste have? For instance in terms of small expansions of dwellings or home-improvements? And how can these developments be linked to “Hof van Cartesius”, as described below?

3 Circular economy in the built environment

3.1 In general

The Ellen MacArthur Foundation (2012), a “global thought leader” in the field of circular economy urges governments, businesses and institutions to make the transition from a linear economy to a circular economy. The Foundation defines the circular economy on their website as follows:

“A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.”

There are numerous reasons why this transition is necessary and even inevitable. One of them being the increasing scarcity of (raw) materials. At the same time, it can be an impelling force behind innovation.

3.2 In the built environment

For the built environment, focus is on eliminating waste through reuse of materials and redesigning building components, systems and logistics. The authors of this paper believe that major reductions in CO₂ emissions and improvements in energy-efficiency amongst others can be achieved by doing so. Thus fostering the transition zero.

Most materials in the construction industry are part of the technical cycle as defined by the Ellen MacArthur Foundation (2012). This means we should design for remanufacturing and refurbishing to keep components and materials circulating in, and contributing to the economy. Circular systems use tighter, inner loops (e.g. maintenance, rather than recycling) whenever possible, thereby preserving more embedded energy and value. The technical cycle involves the management of stocks of finite materials. Use replaces consumption.

3.3 Increased (regional) attention

A recent publication by the Ellen MacArthur Foundation (2015) states that attention towards the circular economy has increased.

In the city of Utrecht this is shown by activities deployed by the Utrecht Sustainability Institute (USI) of which HU is a main sponsor. An example is the most recent publication of Cramer (2015) of USI, called "Circulaire economie: van visie naar realisatie", which translates "Circular Economy: from vision to realization".

In an earlier document of Cramer (2015) of USI, called "Green Deal Cirkelstad – Voorwaarden voor een marktconforme aanpak", she describes how a number of stakeholders in the construction and demolition industry have committed themselves to "close the chain of construction and demolition": the "Green Deal". The thought behind this initiative is to enhance the reuse of demolition waste in the construction circuit in a sustainable way. In other words: to restore or recuperate the quality of used building materials and elements for use in new structures.

One of the parties involved in the "Green Deal" is "Cirkelstad". Cirkelstad offers a platform for progressive, innovative public and private parties that strive towards cities without waste, without jobless people and without (CO₂-)emission. The main focus is to achieve this by reusing demolition waste. Cirkelstad operates in a number of cities including Rotterdam, where practical experience has already been gained in several projects.

3.4 Circular city HUB

In 2015, students of the Institute for Engineering and Design (IED) of HU have researched the possibilities and feasibility of a so-called “circular HUB” in the city of Utrecht. This “HUB” is a physical site, where demolition waste can be gathered, processed and stored, before being reused as construction material. Since the offering of demolition waste and the demand for construction materials will not appear simultaneously, the need for such a “circular HUB” to enhance the circular economy is obvious. The outcome of the research, as published in an article by Henket (2015) in the Dutch professional journal *Cobouw*, stated that a “circular HUB” in Utrecht is indeed feasible and will decrease CO2 emissions significantly because of a higher efficiency in logistics.

Interesting in the context of the above is the document “Verkorte versie Actieplan Goederenvervoer (2015-2018)” by Gemeente Utrecht (2015) – the municipality of Utrecht. In this document measurements and innovations that can contribute to smarter, cleaner, safer and more efficient city logistics are enumerated. The document emphasizes that the city strives towards supplying goods in the city with zero-emission in 2025. Specific attention is paid to optimizing building logistics. The document includes an interview with dr. ir. Ruben Vrijhoef (lector of the research group Supply Chain Redesign in the Built Environment) in which he emphasizes the potential of HUB’s for city logistics. And the fact that these HUB’s will become circular ones in the future.

In 2016 research on the “circular HUB” is being continued at HU by three groups of students with different companies. For each company involved, the way the company can participate in and benefit from the “circular HUB” is questioned. Practical cases, amongst which the renovation of several HU-buildings, are used to test different aspects during the projects.

4 “Hof van Cartesius”: The first open source and circular small urban area development in Utrecht?

4.1 Case introduction and location

The authors of this paper are currently - in close collaboration with professionals and stakeholders from the field - preparing projects and assignments for students of HU in which open source and circular economy in the built environment are combined. The goal is to gain practical insights in open source & circular urban area developments and building projects. Including the potential added value of combining both topics. The Wikihouse-Utrecht initiative as mentioned above is one of these projects. “Hof van Cartesius” (“HvC”, www.hofvancartesius.nl) is another

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Open-source developing, designing and constructing small urban areas with reused demolition waste in the city of Utrecht	Ir. Jeroen Mens Ir. Kitty Vreeswijk	HU University of Applied Sciences Utrecht, the Netherlands	jeroen.mens@hu.nl tel. +31 6 38149116 kitty.vreeswijk@hu.nl

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one. This part of the paper focusses on the plans for “HvC” and the opportunities and challenges that accompany this promising initiative. Information was gained, amongst others, by meetings, talks and an interview with Charlotte Ernst, one of the initiators, and Simone Tenda, project coordinator at “het Uitvindergilde”, which is one of the planned end users of “HvC”.

“HvC” is an initiative by Charlotte Ernst – architect and urban planner – and LINT landscape architecture and won the “open call for initiatives” for the urban transformation of the wasteland called “Vlampijpzone” in Utrecht in May 2014.

The “Vlampijpzone” is a strip of currently unused land between the Vlampijpstraat and the railway tracks from Utrecht to Amsterdam. It is part of the mixed business/ industrial park “Cartesiusweg” (recently renamed to “Werkspoorkwartier”), which is approximately 60 hectares in size and located in the northwest of Utrecht. The area originated in the settlement of the “Werkspoor” factory. This factory left in the 1970’s and since then the area evolved into a place where traditional industrial companies coexist with offices, creative industry, leisure complexes and municipal citycare services.

In 2012, Gemeente Utrecht published the document “Ontwikkelingsvisie Werkspoorkwartier – De transformatie van een bedrijventerrein”, which describes the history, current situation and potential of the regarded area. It characterizes the area as one with problems (lack of unity, no coherence, little interaction, untidy appearance) as well as potential. In recent years, a new appreciation of the area has gained ground, especially by (smaller) creative industries. The municipality of Utrecht states that a traditional approach towards the urban development of this complex area is not suitable. Key words in the development should be innovative initiatives, flexibility and adaptation, combined with a strong and distinctive vision towards the future. Especially the potential and desire for a transformation into a creative, unconventional industrial hotspot is described.

“HvC” is a plan for an experimental, flexible and green working environment at the Vlampijpzone. A testing ground for Utrecht’s circular economy, DIY architecture, collectivity and interaction, bottom-up initiatives and temporary urbanism. The latter as a result of the fact, that the municipality has granted usage of the property for only ten years. This short term is unattractive for professional investors and developers, but the more interesting for small independent & creative entrepreneurs and businesses from within the city.

“HvC” aims to become a catalyst for the transformation of industrial park “Werkspoorkwartier” into a creative, industrial hotspot in Utrecht. Furthermore,

the initiators of “HvC” consider it to be a potential “platform for experiments and crossovers in sustainability, technology and construction”.

4.2 Concept

The concept of the design is based upon the typology of pavilions, clustered around courtyards. The pavilions open themselves towards the inside, thus creating an intimate, collective atmosphere. At the same time, the courts will be publicly accessible, enabling users and inhabitants of nearby areas to also enjoy it. The “green working-environment” will stimulate labor productivity. One of many ideas is to use the inner gardens for urban farming.

“HvC” will be realized in phases. Starting with one cluster of three pavilions around a central courtyard, expanding to both sides, creating a “strip” of buildings interconnected by courtyards during the process (see picture 2).



Figure 2: Hof van Cartesius in a future, intermediate phase of realization (design and image by Charlotte Ernst and LINT Landscape Architecture)

The “organic urban development” and temporary character of the plan forces the users/designers to think and act in flexible, creative solutions. The final outlines of the plan are not fixed. When, over time, other users or other demands arise, the design should be flexible enough to respond to these changes. The structures should be easy and quick to assemble, preferably without professional help and with little means. If necessary, they should be easy to alter and easy to disassemble, transport and assemble elsewhere. Hence the similarities with the concept of the open source initiative of Wikihouse.

When successful, the concept can be replicated to other urban wastelands in need of transformation.

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4.3 Social purpose, collaborations and changing roles

Essential to “HvC” is the fact that it has a social purpose. The aim is creating value for the area and the people involved, instead of making (financial) profit. The initiative aims for creating new urban quality. Bottom-up initiatives like these fill the gap for a certain need, that is seemingly not yet present. It also means a change in roles and responsibilities. The inhabitants that “built their own dream” are often designers, artists, architects or urban planners. In processes like the realization of “HvC”, they also become developers, managers and contractors.

This change also alters the (traditional) role of the municipality. In case of “HvC”, the city of Utrecht is no longer the initiator. Nor the financer or supervisor. In fact, the city of Utrecht should fulfill a role in facilitating the process of the development. This is a new situation for a local government like the municipality. Both parties in the process - initiators and government - have to find new ways of co-operation. This is one of the challenges “HvC” faces today.

For the “collective” of builders and users another question is, how to organize themselves. Who will coordinate the building activities, maintenance, finances, communication etcetera?

The combination of being a testing ground for circular economy combined with open source knowledge sharing is obvious in case of “HvC”, according to Charlotte Ernst. The nonprofit character of the project makes it especially suitable for an open source approach. Traditional, established companies have a certain “fear” for sharing their knowledge, because it can threaten their (short-term) results. Whereas more social-driven initiatives can benefit from it. Initiatives like “HvC” can become future accelerators for innovation and transformation. Precisely because of the absence of fear for sharing. On the other hand, financial funding in these cases is much harder. Where large, established companies have sufficient financial means, small bottom-up initiatives, often struggle to raise funds. This is one of the reasons why the initial idea of mainly attracting small creative businesses is no longer the case. Also larger, more settled companies are welcomed to participate. They can use “HvC” as a showcase for innovative, sustainable developments and/or use it as a testing ground for circular ambitions. They can stimulate, enhance and co-operate with smaller initiatives as part of “HvC”.

An important example is the collaboration with SITA. SITA is one of the biggest waste disposal companies in the Netherlands. SITA not only collects and processes waste products, but also focusses on finding new ways of reusing products. The initiators of "HvC" and SITA are collaborating in finding new ways to reuse demolition waste as building materials in the project.

4.4 Current status

At this moment, the initiators of "HvC" are raising funds in order to realize the first phase. After applying for building permits, start of realization is planned for the second quarter of 2016. The first phase will consist of three pavilions of 850 m² in total (2000 m² of ground surface with gardens included). The total size of "HvC" can become 6000 m² in coming years.

The authors of this paper are planning two types of (research and design) projects with regard to "HvC", starting February 2016. The first is a graduation project for two architecture students of the Institute for Built Environment. The other one is a project for a multidisciplinary group of 6th semester students of the Institute for Engineering and Design. Both groups will approach the project with regard to their own field of expertise, but always in close collaboration and thus enhancing and complementing each other's work. Both authors of this paper will guide and supervise these processes.

The preliminary research questions the students will be working on focus on three areas:

- Construction methods & materials
- Logistics
- Organizational model/growth

4.5 Similar initiatives

In regard to "HvC" and the research described in this paper, a lot can be "learned" from predecessors and resembling projects. For instance "De Ceuvel". This project on a former ship wharf in the North of Amsterdam is, like "HvC", the result of a tender won by a bottom-up, collective initiative and a ten-year lease from the municipality. The initiators turned the former industrial plot – a polluted wasteland – into a "regenerative urban oasis": wasted houseboats from the city were turned into offices and ateliers for creative and social enterprises. These were placed in a landscape of soil-purifying plants. By doing so, after ten years the city council, who co-financed the project, will retrieve a less polluted parcel of land.

"De Ceuvel" is currently in use and has generated a significant amount of publication and attention. In a personal conversation with architect Wouter Valkenier, one of the initiators and team member of "De Ceuvel", experiences and "lessons learned" were discussed. One of these experiences is that the project already has a positive impact on the surrounding areas. In a way, that it attracts numerous new and other users.

"De Ceuvel" has a high level of self-sufficiency. "Mainstream" technology (e.g. solar panels) could not be used to achieve this, because the (long-term) investment needed for such technology did not suit the temporary, short-term use of the project. Instead, self-developed innovations and technologies were developed and used. This "first-generation" technology, self-evidently, showed flaws, which had to be dealt with.

Another experience worth mentioning concerns the communication of the collective. Especially with external parties. It has proven essential to invest time and energy in communication processes in order to prevent miscommunication and mutual frustrations.

Future interviews and collaborations with "pioneers" like the initiators of "De Ceuvel", but also for instance "Plug In City" in Eindhoven, will provide further valuable input for the research described in this paper and "HvC".

5 Conclusions

In 2016, the outcomes of the described researches and case studies will provide answers to the questions both authors have. Most importantly, it will proof whether or not (the development of small urban areas in) cities can benefit from reusing demolition waste and a circular HUB. And whether or not an open source approach has the potential to accelerate these innovations. And if so: in what way and with which "protocols"? In addition, it will help to further define the concept of "open source" in the built environment.

Furthermore it will tell us, whether or not a bottom-up and non-profit driven concept like "HvC" is successful in turning wastelands into use. And if it might be possible to replicate it to other urban wastelands in need of transformation.

By doing so, this research contributes to the challenges addressed to as the "Transition Zero".

This research is part of the research program of the research group Supply Chain Redesign in the Built Environment of HU. It is in multiple ways related to other researches within this group. The authors would like to refer to other papers as part of the SBE16- Transition Zero Conference for gaining further insight in these relationships.

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Open-source developing, designing
and constructing small urban areas
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in the city of Utrecht

AUTHORS
Ir. Jeroen Mens
Ir. Kitty Vreeswijk

ORGANIZATION
HU University
of Applied Sciences
Utrecht, the Netherlands

MAIL ADDRESS
jeroen.mens@hu.nl
tel. +31 6 38149116
kitty.vreeswijk@hu.nl

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COMPARING SUSTAINABLE RENOVATION PROCESSES ON TENANT PARTICIPATION TO FOSTER URBAN AREA TRANSITIONS

In urban transitions, one issue is the improvement of building stock energy performance. The current reasoning is often that the promise of increased comfort and health is attractive to residents. However, this does not always result in acceptance and long-term energy reduction. We draw lessons from case studies of renovation projects. It turns out that hardly any neighbourhood is suitable from scratch. Key findings are: an observed innovation-focused process optimized resident participation but risks excluding them from shaping their future. Conversely, an observed resident-led process did not achieve its initial goal due to process barriers, but developed locally based, transferable, organisational learning.

1 Introduction

Sustainable renovation aims to improve buildings so as to decrease energy consumption and improve thermal comfort and indoor air quality for residents. In the Netherlands and several other European countries, a major initiative is underway to give the next wave of housing renovation a sustainability push. This serves to achieve European CO₂ emissions reduction goals and ensure sustainability (Climate KIC, 2015; Steensma et al, 2016). Technology is developed far enough to renovate homes so that they produce as much energy as their occupancy consumes, and are thus 'zero-energy'. However, an often-voiced concern has been that in the case of rental properties, tenants are often not engaged with these goals. The case in point is that in the Netherlands the 70% tenant opt-in needed is not always achieved (e.g. Sijpbeer et al, 2015). Additionally, if a renovation does go through, rebound effects often occur afterwards, meaning that occupancy consumes more energy than predicted in calculations (e.g. Galvin, 2014). The reasons are still unclear, but are presumed to lie in residents' post-renovation behaviour and interaction with their home systems (e.g. Chiu et al, 2014). These sources concur that a careful process of resident participation ahead of renovation could address these issues.

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Comparing sustainable renovation processes on tenant participation to foster urban area transitions	Dr. Dipl. Des. Stella Boess Dr. Olivia Guerra Santin Dr. Sacha Silvester Ing. Peter Budde Ir. Ing. Hannah Frederiks	Delft University of Technology Delft, the Netherlands University of Applied Sciences Rotterdam, the Netherlands	s.u.boess@tudelft.nl tel. +31 15 2783029 o.guerrasantin@tudelft.nl s.silvester@tudelft.nl p.c.j.budde@hr.nl h.c.frederiks@hr.nl

In this paper we present an analysis of three cases of renovation processes. We seek to pinpoint characteristics in each of them that are likely to affect the residents' motivation to participate and to engage with the issue of energy saving. These characteristics turn out to be connected to neighbourhood issues.

2 The phenomenon of acceptance, or opt-in

When people are not involved in the sustainability reason for a renovation, they are not given the chance to adopt and contribute to the global imperative of climate change mitigation (Mourik et al, 2015). By Dutch law, for example, 70% of tenants have to agree to a proposed renovation project going ahead. In practice, this results in tenants often being viewed as a potential stumbling block for a project, and there are examples of projects that have indeed failed to go ahead (Sijpbeer et al, 2015), due to issues such as residents' built-up anger about overdue maintenance. In any situation, simply asking people to agree to something new is never likely to result in higher than around 50% opt-in, which consists of the 'late majority' and the 'laggards' (Moore, 1991). Interestingly, Sanders (2014) claims that only social cohesion and local initiative can lift resident interest above this general level of opt-in. While there has recently been an increase in focus on residents' use practices (e.g. Kuijter & Bakker, 2015), this paper investigates another issue of interest with regard to resident opt-in, namely the overall organisation of the development process. Sustainable renovation could therefore be more than a choice for improved comfort and health - it could also be an opting in to the idea of a sustainable present and future.

2.1 Design participation in a renovation process

To investigate the position of residents in currently existing renovation processes and to address resident motivation, we adopt the perspective of design participation. Lee (2008) stated that it was defined as "bringing 'everyman' into the field of design" since the 1970s, and that participation in architectural design was seen as an economic necessity, a chance for neighbourhood renewal, and it became part of government policies. Lee (2008) provides a framework that we will use to study current processes and to investigate the type of design participation they facilitate. Lee (2008) states that designers, through their disciplinary skillset, can improve such processes by working with the residents' aesthetic concerns as well as their use practices, by translating resident needs into design proposals more directly than social scientists do, and by analysing and challenging the status quo of renovation processes.

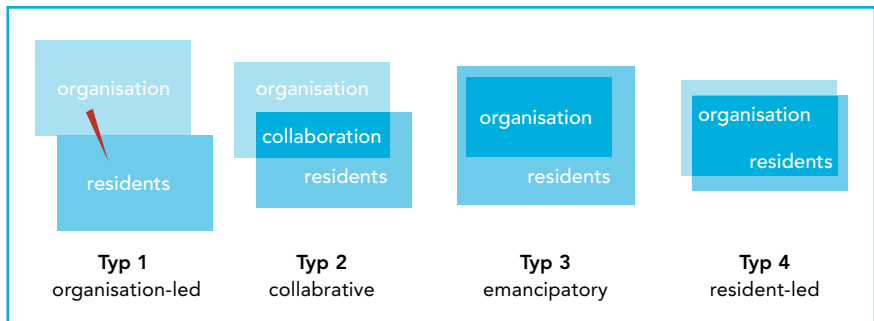


Figure 1: A typology of design participation in processes, adapted from Lee (2008)

The typology in Figure 1 enables us to distinguish between levels of design participation in development processes. By 'organisation' here is meant, the total of experts and entities (including designers) intervening in the lives of the residents. The processes Lee (2008) identified range from a primary innovation aim, in which residents are only consulted as representatives of the context, via a collaborative process and a process in which experts and entities support residents' emancipation, to a completely 'resident-autonomous' process in which these organise their own future and only ask specialists to provide specific services. The users' - or residents' - motivation varies according to their autonomy and ability to participate. Particularly self-help sector practitioners regard the first extreme as 'tokenistic', and participation pointless. Most approaches lie between these extremes. In our study we aligned three observed processes along the types sketched by Lee (2008), in order to compare them on their effect on residents and their motivation.

3 Method

We have studied three cases of renovation projects. These case studies were partly reported earlier (Boess, 2015), though not in the process view described here. The authors were not actively involved in the processes described, merely observing them from a perspective of interest in their form of design participation. We used a multiple case study approach as Runeson and Host (2009) formulated it for software engineering, because it is adapted from general case study methodology to study work that develops something, is project oriented, and advanced design work rather than routine work (Runeson and Host, 2009, pp. 132-133). The cases were studied by visiting an event related to each of the cases. In the first case, this was a visit to a building site where a renovation was in progress. This was combined with interviews of two stakeholders: one from the build process side, and one from the resident

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Comparing sustainable renovation processes on tenant participation to foster urban area transitions	Dr. Dipl. Des. Stella Boess Dr. Olivia Guerra Santin Dr. Sacha Silvester Ing. Peter Budde Ir. Ing. Hannah Frederiks	Delft University of Technology Delft, the Netherlands University of Applied Sciences Rotterdam, the Netherlands	s.u.boess@tudelft.nl tel. +31 15 2783029 o.guerrasantin@tudelft.nl s.silvester@tudelft.nl p.c.j.budde@hr.nl h.c.frederiks@hr.nl

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side. In the second case, this was a visit to a model house and attendance of a symposium in which insights from the process were discussed, including resident responses. This was combined with an expert interview with a building process innovation professional. In the third case, the research was a visit to an event at which professionals and residents came together to discuss progress in their initiative. This was combined with interviews of the involved professionals. In all cases, the empirical work was augmented with the study of websites and published material related to the case. The three process design cases were analysed qualitatively by characterizing them according to Lee's (2008) typology, presented above. All three processes involved social housing.

4 Results

The four steps generally used in building process management, as stated by Wamelink (2009, p. 4) and Breukers et al (2014) are: design, preparation, renovation, and use. Design participation as defined by Lee (2008) can be involved in all of these steps, although this is not always the case. The processes studied are divided into a larger number of steps that emphasize the first three parts, due to the focus on design participation. Figure 2 compares the three processes by steps, context, and level of participation, based on Lee (2008).

In Process 1 in Figure 2, a networked consortium functions in the background of a replicable process. This has two key effects. Firstly, what residents see of the process is much shorter than in the other two processes. The residents are offered an attractive product, supported well and only experience the process for a short time. Secondly, the networked learning in the background provides a great basis for product development and industrialisation. In effect, it is an industrialised process as in car production, where the finished product is in the showroom and people can select it and 'buy' it.

In Process 2, organisations contact local key persons and these provide access to neighbourhood networks. A housing corporation and a builder run the process and organise an independent advice-partner for the residents. The process is organisationally replicable but inclusive of local issues (for example, it included a local park that residents cared about). Knowledge remains largely limited to this consortium. The process resembles a tailor's craft, making a product according to needs and a pattern while the customer waits for it. The product is adapted until it fits.

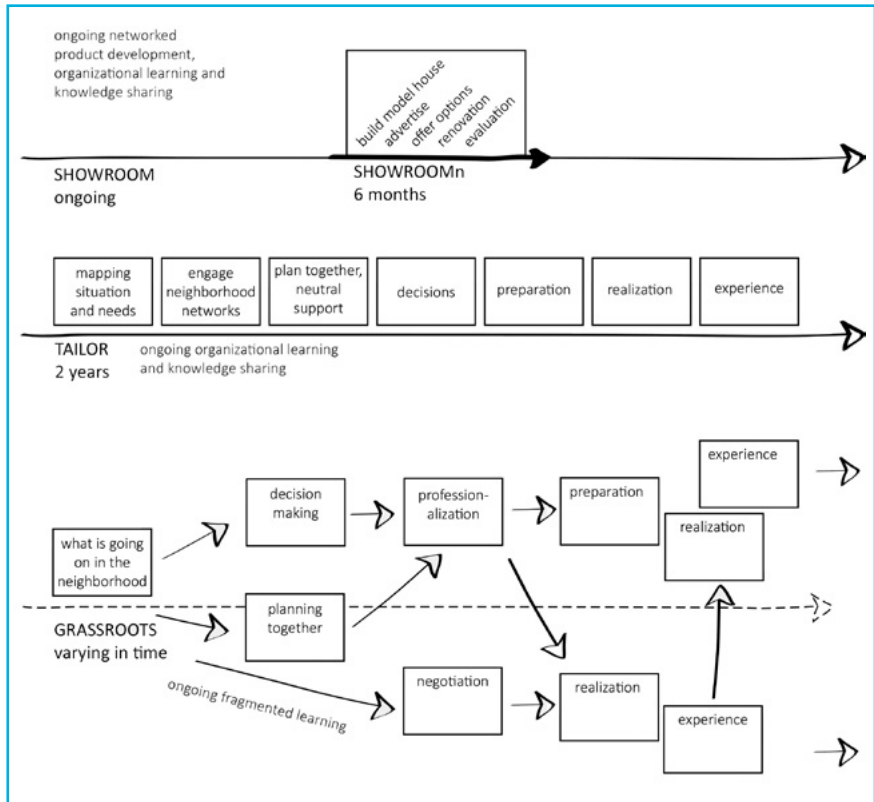


Figure 2: The three types of processes observed and their steps and organisation

Process 3 started with a group of residents noticing something about their neighbourhood: the potential of using heat from a local pool for their houses. They sought to realise this aim, but did not reach it. Instead, this 'bottom-up' process resulted in a diversification of activities, among them professionalisation. This process is grounded in the context of the dwelling and neighbourhood and awareness of local issues. Participants adapt initial aims as they encounter barriers and form new ones as they learn. The process resembles a seed being dropped into ground that reveals its shape as it grows and interacts with the plants around it. Much negotiation and surprises ensue.

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4.1 Comparing the processes on design participation types

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Process 1 is clearly of the organisation-led type, when compared with Figure 1. Its main aim is to address the need for CO2 reduction by developing and marketing new housing technology, in other words, innovation. The organisation aims to make the resident involvement as smooth and as attractive as possible, to facilitate wide adoption of the technology and upscaling. When compared with the other two processes, a risk can be identified that the short period of involvement, and the reduced knowledge of residents on how the process works, limits their potential to contribute via design participation and to help shape the future of sustainable housing renovation.

Process 2 resembles the collaborative type in Figure 1. It similarly aims to address the need for CO2 reduction by developing new housing technology, but the negotiation process is localised and hence offers more flexibility. Because the residents are close to the process but well supported, they can contribute to the process. However, it was found that they did not always have sufficient opportunity to anticipate, understand and monitor their new home situations. The residents we visited were unable to fully explain the effects of their home systems, because these were still standardised. Nonetheless, they had been able to change some design decisions affecting their home lives directly. Process 2 is too long, timewise, to be economically viable for upscaling.

Process 3 is a mix of the 'emancipatory' and 'resident-led' types. Some of the residents in this case were themselves architects, enabling the group to bring an analytical perspective to the process. The hurdles for their original aim proved too high. Similarly, Lee (2008) mentions the experience of a process in which the design participation was in the end rejected by a consortium because there were no structures in place to acknowledge it and include it in the overall process. The residents in process 3 also learned through experience that the field is currently organised in such a way that design participation is difficult or impossible. They therefore started developing knowledge and skills, and are now advising proponents of process 1 and others on design participation, from a systemic perspective as e.g. advocated by Lorek & Vergragt, 2015.

Process 3 has generated a high and lasting level of motivation for a small group of residents who went on to professionalise in this field and become design participants in it. The residents of Process 1 and 2 assessed them as successful, but stayed in their role as residents.

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Comparing sustainable renovation processes on tenant participation to foster urban area transitions	Dr. Dipl. Des. Stella Boess Dr. Olivia Guerra Santin Dr. Sacha Silvester Ing. Peter Budde Ir. Ing. Hannah Frederiks	Delft University of Technology Delft, the Netherlands University of Applied Sciences Rotterdam, the Netherlands	s.u.boess@tudelft.nl tel. +31 15 2783029 o.guerrasantin@tudelft.nl s.silvester@tudelft.nl p.c.j.budde@hr.nl h.c.frederiks@hr.nl

197 In a conclusion from these three processes, and in order to maximise the potential for design participation to contribute, an ideal process would be:

- longer than process 1 in the residents' experience, but as efficient and supported by a strong knowledge base as process 1
- shorter than process 2, but still inclusive of local issues and independent support for residents
- facilitating original ideas and organisational (including resident) learning like process 3

5 Discussion

We have characterised three types of processes observed in practice and compared them using Lee's (2008) framework on their type of design participation and resident motivation. From the broader perspective of Human Development as described by Malik et al (2014), the pure application of Process 1 should be seen as problematic, since it reduces human dwelling and social cohesion to a consumption mechanism that does not include empowerment. Process 2, in itself, is time- and resource-consuming and may not lead to the desired CO2 reduction within EU goals because it is too expensive to upscale. Process 3 is fragmented, likely to encounter hurdles, and may not always succeed, but has the most potential for human development since it also addresses such issues as income- and social cohesion goals by challenging current processes. Particularly, it can result in professionalisation as shown here, which in turn provides value and innovation potential to change other processes. That is why the learnings from such processes should be sought out and made available to organisations aiming for urban transition through sustainable renovation of social housing stock.

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TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas Miguel Fontela Martínez	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com tel. +34 917490001
	Jelle Bart van Breest	IDP Sabadell, Spain	jvanbreest@idp.es
	Toni Salminen Jarno Rinta-Valkama Joe Dickinson	Fortum Espoo, Finland	toni.salminen@fortum.com jarno.rinta-vaikama@fortum.com
	Raquel Iglesias	Electric Corby Corby, United Kingdom	joe@electriccorby.co.uk
Antoine Giachetto	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat	
		Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr

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INCREASING ENERGY EFFICIENCY IN EUROPEAN DISTRICTS THROUGH ICT TOOLS: DISTRICT OF FUTURE PROJECT

The European project District of Future (DoF) is focused on reducing energy consumption, increasing energy efficiency and using renewable energy in buildings. The project aims to demonstrate 30-40% reduction of the energy consumption and CO2 emissions of 3 demonstrator districts, i.e. in the UK (Corby), Spain (Sabadell) and France (Orleans) utilising an ICT platform based on FIWARE. DoF will provide buildings with an energy analysis and modelling platform to improve energy efficiency and help authorities and citizens make appropriate decisions.

1 Introduction

Cities are converting into the centre for business activity and act as the socio-economic nuclei in European countries. In this context, we consider necessary to adapt to this new era in which an improvement of the organization and an optimization of the resources has become an essential task. DoF is a pioneer in the integration of heterogeneous data, which is one of the key aspects behind the concept of smart cities. It proposes the creation and validation of an open environment, which enables an optimization in energy management, having defined a suitable framework to integrate all the elements that take part in different levels of a city district. The project is a practical demonstration of energy data integration from heterogeneous sources including: hardware and software applications, real time and historical data, and different buildings in cities. The project aims to demonstrate 30-40% reduction of the energy consumption and CO2 emissions of 3 demonstrator districts i.e. in the UK (Corby), Spain (Sabadell) and France (Orleans). It aims to demonstrate the

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com
	Miguel Fontela Martínez		mfontela@exeleria.com
	Jelle Bart van Breest	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Toni Salminen	Fortum	toni.salminen@fortum.com
	Jarno Rinta-Valkama	Espoo, Finland	jarno.rinta-vaikama@fortum.com
200	Joe Dickinson	Electric Corby Corby, United Kingdom	joe@electriccorby.co.uk
	Raquel Iglesias	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat
	Antoine Giachetto	Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr

important role of ICT (Information and Communication Technologies) in optimizing district energy systems in the transition to a zero carbon scenario.

One of the challenges of this project is to integrate the management of different sources of energy production and consumption from a neighbourhood. This will be achieved by means of a model driven by innovative ICT architecture, in which data is collected in a homogenising platform called BDAC (Big Data Aggregation & Collection), which standardizes and sends data to the “DoF platform” which rests within the FIWARE environment. Once data is available to the DoF platform, energy efficiency applications can be integrated, such as optimisation and simulation tools to propose energy efficiency improvements at a district level. Whereas the main aim of the project is to achieve a method to make a 30-40% saving of energy consumption with the implementation of the DoF ICT platform situated on the FIWARE cloud, the ability to quantify energy savings through district network optimisation is also a key point to the DoF platform. In this paper, a detailed description of the optimization and simulation tools used within the project is disclosed.

2 Use Cases description

When developing optimization solutions, it must be acknowledged that city districts vary significantly in their characteristics, structure, size, climate and culture and therefore also in their energy generation, consumption and efficiency. The availability of real-time energy information and Big Data will enable us to optimize the energy load balancing of the districts.

Our city demonstrators are:

- **Sabadell** (Spain). The city of Sabadell is located in Spain and possess three different types of facilities:
 - Social Housing: 31 dwellings built with materials to generate low consumption are monitored. Centralized heat production. Highly efficient geothermal exchange. Domestic Hot Water (DHW) production through geothermal pumps with direct exchange of cold

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas Miguel Fontela Martínez	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com tel. +34 917490001
	Jelle Bart van Breest	IDP Sabadell, Spain	jvanbreest@idp.es
	Toni Salminen Jarno Rinta-Valkama Joe Dickinson	Fortum Espoo, Finland Electric Corby Corby, United Kingdom	toni.salminen@fortum.com jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
	Raquel Iglesias Antoine Giachetto	Ajuntament de Sabadell Sabadell, Spain Ville d'Orleans Orléans, France	riglesias@ajsabadell.cat agiachetto@ville-orleans.fr

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- 'Can Marçet': Public building and police office. Geothermal energy, monitoring system
- 'Can Llonch' Pneumatic Waste Collection Central: Power consumption monitoring, photovoltaic panels installed to produce energy
- **Corby** (United Kingdom). This city is situated in the United Kingdom and consists of 4 different facilities:
 - ZEB Houses: Hybrid photovoltaic and solar thermal panels accompanied by a home automation system
 - Oakley Vale Primary School: biomass boiler, solar-thermal unit and large PV array
 - Corby Business Academy: underfloor heat distribution system, data monitoring, and a Building Management System (BMS)
 - Corby Enterprise Centre: small solar-thermal array and a dual fuel gas and oil boiler
- **Orléans** (France). This use case site is located in France and offers five public facilities:
 - Public Library Maurice Genevoix (Médi@thèque): Two heat pumps (heating and cooling). Connection to the electric grid. Real time consumption monitoring
 - Pauline Kergomard Public School: 200m2 solar PV. Connection to the Biomass Plant, solar cells. Screen monitoring production and consumption of energy
 - Social Housing: two social housing with 25MW biomass plant energy source connected to the heating network
 - Day Nursery La Bolière: Connected to the District Heating network of Dalkia. It provides DHW and energy for the heating of the building
 - Biomass CHP plant: it produces heat to the local DH network and electricity

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	Rubén Cánovas Mas	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com
	Miguel Fontela Martínez	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Jelle Bart van Breest	Fortum Espoo, Finland	toni.salminen@fortum.com
	Toni Salminen	Electric Corby Corby, United Kingdom	jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
202	Raquel Iglesias	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat
	Antoine Giachetto	Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr

3 ICT Platform Architecture

The DoF project has designed a platform (Figure 1) which collects the data coming from the energy meters, which is then used to process and optimise the districts.

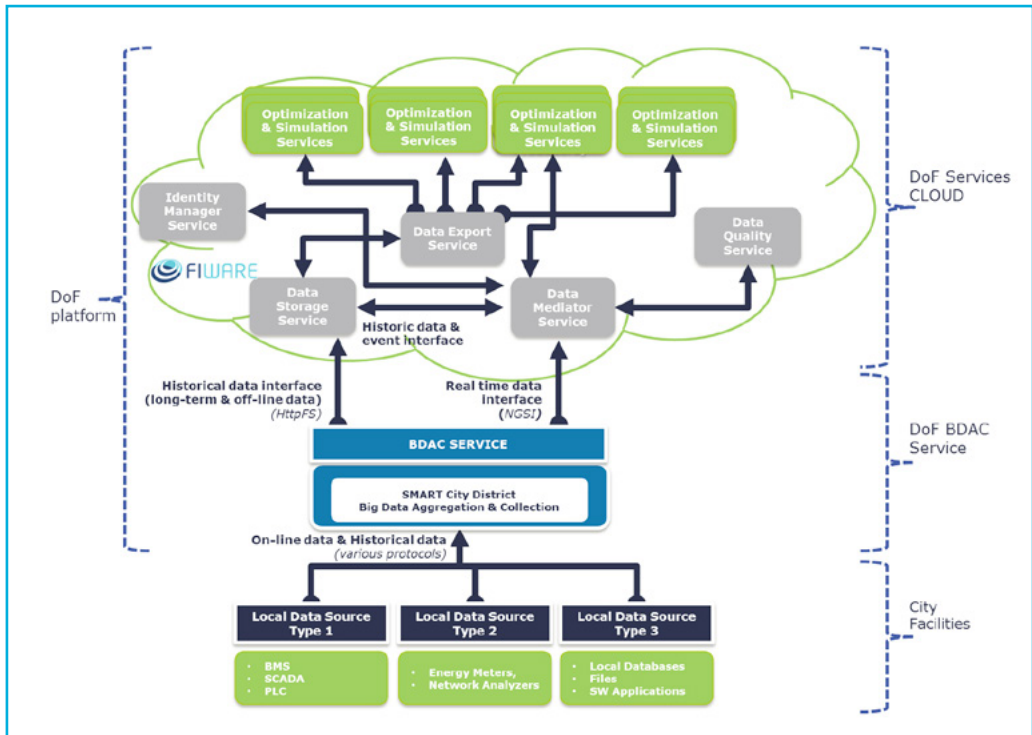


Figure 1: DoF Platform Architecture System

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas	Exeleria	ruben.canovas.mas@everis.com
	Miguel Fontela Martínez	Madrid, Spain	mfontela@exeleria.com
	Jelle Bart van Breest	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Toni Salminen	Fortum	toni.salminen@fortum.com
203	Jarno Rinta-Valkama	Espoo, Finland	jarno.rinta-vaikama@fortum.com
	Joe Dickinson	Electric Corby Corby, United Kingdom	joe@electriccorby.co.uk
	Raquel Iglesias	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat
	Antoine Giachetto	Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr

The following are the key components of the platform:

- *City facilities*: buildings and facilities are monitored. The data can be of any kind and may come from different systems: energy consumption, generation or transportation data. As monitoring systems we use electrical meters/network analysers, BMS/SCADA/PLC systems (Building Management System/Supervisory Control And Data Acquisition/Power Line Communications), and thermal meters (calorimeters), as well as weather stations. Heterogeneous and very diverse block without standardization
- *DoF BDAC*: Big Data Aggregation & Collection. This software service manages the data collection from heterogeneous data sources every 15 min using different communication protocols. Furthermore, it has the function of standardizing data treatment and preparation for further processing done by the DoF services in the cloud: it manages the data "anonymization" and data aggregation where needed and converts the captured data into the correct format so that they can be uploaded and stored in the FIWARE platform. The communication with the platform has been standardized for easier communication between existing systems
- *DoF Services Cloud*: it provides the initial data storage for the DoF data and is also the place where the DoF Optimization and Simulation Services will process the data. The results of the Optimization and Simulation Services may be visualized and/or stored in the cloud

4 Optimization tool

The main quantitative aim of the DoF project is to demonstrate a 30-40% energy savings with the implementation of the ICT platform, therefore the measurement of the energy savings which is generated is a key indicator of success.

In order to accomplish the objective, different bespoke optimisation tools are being developed within the DoF project:

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas Miguel Fontela Martínez	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com tel. +34 917490001
	Jelle Bart van Breest	IDP Sabadell, Spain	jvanbreest@idp.es
	Toni Salminen Jarno Rinta-Valkama Joe Dickinson	Fortum Espoo, Finland Electric Corby Corby, United Kingdom	toni.salminen@fortum.com jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
	Raquel Iglesias Antoine Giachetto	Ajuntament de Sabadell Sabadell, Spain Ville d'Orleans Orléans, France	riglesias@ajsabadell.cat agiachetto@ville-orleans.fr

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4.1 Buildings and/or systems Energy Modelling Tool (Energy Baselines)

With the DoF platform historical data as an input, the tool will develop a multi-variable mathematical equation which describes the energy behaviour of the building/system and how the building/system energy consumption relates to different variables (independent variables).

This mathematical model will be based on statistical analysis and aligned with the best practices related to the energy measurement and verification international protocols: IPMVP EVO Protocol and ASHRAE Guidelines.

Once an energy baseline is defined for a building/system, it will be used to calculate the energy savings (Figure 2) when a change is made in a system or an installation within the project or in the future. In short, the model will define the initial energy situation for the building/system.

Furthermore, the energy data input for the tool will be used to define the energy profiles for the buildings/systems so that an energy dashboard report will be an output of the tool alongside with the energy baseline. The energy dashboard will help to detect abnormal energy patterns, ghost consumptions and comparable buildings/systems benchmarking, among others.

The advantages of this tool are:

- Increase energy savings, as it serves as a source of information to govern a process
- Serve as a reference for the calculation and billing based on the savings in the case of the implementation of an energy management
- Improve the design and operation of the facilities, creating a database with the actual operating conditions of facilities

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com
	Miguel Fontela Martínez	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Jelle Bart van Breest	Fortum Espoo, Finland	toni.salminen@fortum.com
	Toni Salminen	Electric Corby Corby, United Kingdom	jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
205	Joe Dickinson	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat
	Raquel Iglesias	Ville d'Orleans Orléans, France	giachetto@ville-orleans.fr
	Antoine Giachetto		

The basic equation used to evaluate the energy saving is:

Energy Savings [kWh]

= Energy consumption Reference Scenario (energy baseline)
- Energy Consumption PostImplementation ± Adjustments

*Energy Baseline Consumption [kWh] = 30.787,13 + 51,58 * GDC + 66,52 * GDR*
R2 = 0,64

Where GDC is Heating Degree Days (15°C)
GDR is Cooling Degree Days (20°C)
R2 is the statistical measure of the equation

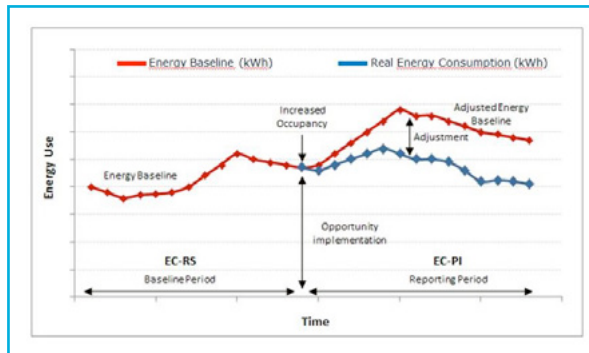


Figure 2: General overview of energy savings calculation

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com
	Miguel Fontela Martínez	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Jelle Bart van Breest	Fortum Espoo, Finland	toni.salminen@fortum.com
	Toni Salminen	Electric Corby Corby, United Kingdom	jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
	Jarno Rinta-Valkama	Ajuntament de Sabadell Sabadell, Spain	rglesias@ajsabadell.cat
206	Joe Dickinson	Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr
	Raquel Iglesias		
	Antoine Giachetto		

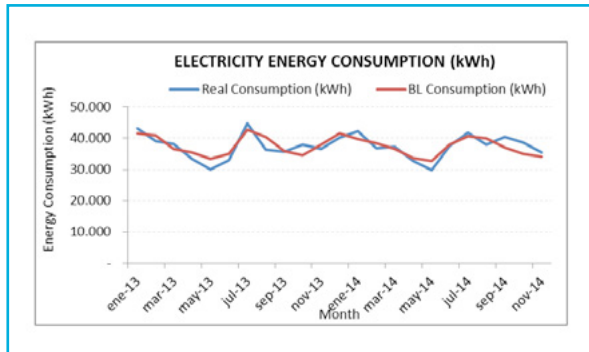


Figure 3: Electrical Energy Baseline of 'Can Marcet'

4.2 Energy Dashboard Tool (EDT)

With the DoF platform using historical data as an input, the tool will develop energy data aggregated figures displayed through a dynamic dashboard. It shows a graphical representation of the current status and historical trends of a system or an installation and the key performance indicators.

This tool is based in Microsoft Excel format and presents the information graphically with a visual presentation of the information and statistics in a far easier way for cities and users to analyse and understand.

It will acquire the data automatically from the DES (Data Exportation Service) that is being developed to make the access to the data easier. The tool, which uses Pivot Tables and Visual Basic, aggregates the information and shows it, using segmentation and targeting that helps the user to decide the period or facilities to study.

Within this tool, KPI's will be defined and their progress will be measured. KPIs are defined as a metric tied to a target and can help to strengthen culture of energy savings.

Different approaches are taken into account within the tool:

- General Energy Dashboard
- Summarized aggregated information of energy use for systems, buildings, cities...

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Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas Miguel Fontela Martínez	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com
	Jelle Bart van Breest	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Toni Salminen Jarno Rinta-Valkama Joe Dickinson	Fortum Espoo, Finland Electric Corby Corby, United Kingdom	toni.salminen@fortum.com jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
	Raquel Iglesias Antoine Giachetto	Ajuntament de Sabadell Sabadell, Spain Ville d'Orleans Orléans, France	riglesias@ajsabadell.cat agiachetto@ville-orleans.fr

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- Comprehensive figures that include historical comparisons: Energy hourly profiles, energy distribution in operating schedule
- KPIs definition for easy understanding of the information
- Upscaling tool
- This tool will enable users to upscaling at district level by combining and multiplying by different factors the real data coming from facilities, that allows to generate different scenarios based on real data profiles and find out which would be the best energy mix for a planned district in the short or medium term for municipalities

Taking into account the cities concerns related to the outcomes and outputs of the project, the energy dashboard tool connects the data from the existing real-time energy meters and additional real-time energy meters installed within the project throughout the cities.

This tool displays a visual based analysis of the energy data allowing project technical partners and cities to visualize and find out easily energy patterns, phantom consumptions, bad operational habits, etc.

The energy dashboards will be generated in different project stages to visualize changes in the energy patterns. Technical reports will be created through the energy dashboard in order to give advice to the city managers including the analysis of the energy profiles and recommendations in how they can alter the energy consumption to reduce their energy consumption, optimizing the operation of the systems or installations.

The energy dashboard will help to compare between different stages of the same installation, before and after the operational changes have been made.

Figure 4 are some examples of the analysis of the energy dashboard:

TITLE
 Increasing energy efficiency in European districts through ict tools: district of future project

AUTHORS
 Eduard Benasques Borau
 Rubén Cánovas Mas
 Miguel Fontela Martínez
 Jelle Bart van Breest

ORGANIZATION
 Everis Spain, EVE
 Barcelona, Spain
 Exeleria
 Madrid, Spain
 IDP
 Sabadell, Spain
 Fortum
 Espoo, Finland
 Electric Corby
 Corby, United Kingdom
 Ajuntament de Sabadell
 Sabadell, Spain
 Ville d'Orleans
 Orléans, France

MAIL ADDRESS
 eduard.benasques.borau@everis.com
 tel. +34 934947700
 ruben.canovas.mas@everis.com
 mfontela@exeleria.com
 tel. +34 917490001
 jvanbreest@idp.es

Toni Salminen
 Jarno Rinta-Valkama
 Joe Dickinson

toni.salminen@fortum.com
 jarno.rinta-vaikama@fortum.com
 joe@electriccorby.co.uk

Raquel Iglesias

riglesias@ajsabadell.cat

Antoine Giachetto

agiachetto@ville-orleans.fr

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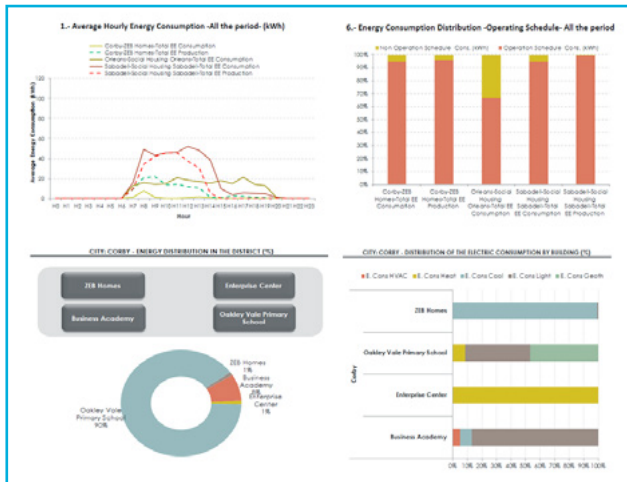


Figure 4: Energy analyses of districts in DoF

4.3 4.3 GHG Emissions Assessment Tool

On the basis of the results of the Energy Modelling Tool, it will calculate the Green House Gasses associated with the energy savings based on international calculation rules: the ISO Reference standards.

Based on these tools and their results a District Energy Efficient Planning report will be developed, which will serve as a guide of good practices in the use and efficient power generation and consumption.

5 District energy simulation tool

As part of the study of the energy consumption at district level, calculation models of the DoF project use cases created with the APROS-simulator. APROS is a dynamic process simulator developed by Fortum corporation and VTT technical research centre since 1986. APROS had its beginnings in thermal hydraulics and has since been extended in process components, nuclear reactors, automation systems, chemical reactions, electrical systems, paper mills, solar power, etc. Models are

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas	Exeleria	ruben.canovas.mas@everis.com
	Miguel Fontela Martínez	Madrid, Spain	mfontela@exeleria.com
	Jelle Bart van Breest	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Toni Salminen	Fortum	toni.salminen@fortum.com
	Jarno Rinta-Valkama	Espoo, Finland	jarno.rinta-vaikama@fortum.com
209	Joe Dickinson	Electric Corby Corby, United Kingdom	joed@electriccorby.co.uk
	Raquel Iglesias	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat
	Antoine Giachetto	Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr

built out of a basic component library and a topology is created in a GUI. Models may consist of physical first principle calculation side by side with logic, transfer function and controller models. Calculation considers flow (6 equation, 5 equation or homogenous), chemical and nuclear reactions, heat exchange, phase changes, automation and logic and electricity.

First of all, a baseline model of a district was created. Models of our use case buildings were created and added to the model. These buildings consist of the envelope, ventilation, heating and cooling systems, and of a model of electricity and heat depending on human presence. Solar components were used to connect radiation to house envelope and PV or solar heating. In addition to the building models, certain district level systems were configured. In two of the districts, a district heating network, enhanced production capacity and energy storage were modelled. Outside of the districts were boundary conditions; external networks such as electricity grid and gas network.

Figure 5 shows the extent of systems/phenomena considered and their relation to the single building electricity and heat balance.

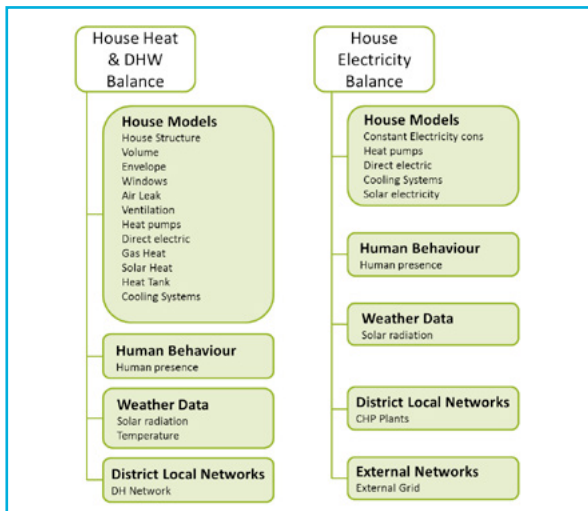


Figure 5: APROS Building model extent

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas	Exeleria	ruben.canovas.mas@everis.com
	Miguel Fontela Martínez	Madrid, Spain	mfontela@exeleria.com
	Jelle Bart van Breest	IDP Sabadell, Spain	tel. +34 917490001 jvanbreest@idp.es
	Toni Salminen	Fortum	toni.salminen@fortum.com
	Jarno Rinta-Valkama	Espoo, Finland	jarno.rinta-vaalkama@fortum.com
210	Joe Dickinson	Electric Corby Corby, United Kingdom	joe@electriccorby.co.uk
	Raquel Iglesias	Ajuntament de Sabadell Sabadell, Spain	riglesias@ajsabadell.cat
	Antoine Giachetto	Ville d'Orleans Orléans, France	agiachetto@ville-orleans.fr

After baseline models, energy upgrade options were implemented in the models. These included improvements such as heat recovery, envelope insulation, awning blinds, heat pumps, photovoltaic, solar heat, CHP (combined heat and power). As baseline simulation (over a year) and upgrade simulation results were available, the results could be compared and the effect of different options appraised. In Figure 6 some of the district model building modules are laid on top of a map.



Figure 6: Part of a district model in Apros User Interface

6 Conclusions

After the simulation and optimization tests have been carried out, and it has been demonstrated that it is possible to reduce the energy consumption and the CO₂ emissions as it was agreed to, we are able to set behaviour patterns according to a defined model and build a predictive system for the use and generation of energy. This information allows us to learn from previous experiences and outcomes so that we can apply measures in order to reduce the energy consumption and CO₂ emissions.

Potentially, the tool developed can be used as a local authority's tool for developing local and regional plans as well as becoming a requirement for large scale developments. The tool may also be used to assess existing districts to help determine their renovation/retro fit action.

On the whole, this will help both the city managers and the final users to wield control of their energy consumption and, therefore, this will have an impact on the district's economy.

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
Increasing energy efficiency in European districts through ict tools: district of future project	Eduard Benasques Borau	Everis Spain, EVE Barcelona, Spain	eduard.benasques.borau@everis.com tel. +34 934947700
	Rubén Cánovas Mas Miguel Fontela Martínez	Exeleria Madrid, Spain	ruben.canovas.mas@everis.com mfontela@exeleria.com tel. +34 917490001
	Jelle Bart van Breest	IDP Sabadell, Spain	jvanbreest@idp.es
	Toni Salminen Jarno Rinta-Valkama Joe Dickinson	Fortum Espoo, Finland Electric Corby Corby, United Kingdom	toni.salminen@fortum.com jarno.rinta-vaikama@fortum.com joe@electriccorby.co.uk
	Raquel Iglesias Antoine Giachetto	Ajuntament de Sabadell Sabadell, Spain Ville d'Orleans Orléans, France	riglesias@ajsabadell.cat agiachetto@ville-orleans.fr

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STUDENT BATTLE AS AN EDUCATIONAL TOOL FOR ENERGY TRANSITION

Both for reasons of climate change, security of supply and economics, the dependency on fossil fuels for the energy demands of houses needs to be decreased. The Dutch government has set goals for the realization of a transition to an energy neutral built environment and is implementing measures to accelerate the transformation of existing houses to net energy neutral, the so-called 'zero on the meter' houses. This transformation shall be implemented in complete neighborhoods. The municipalities are researching the opportunities to transform neighborhoods to zero energy. Sub questions are: How can we get the neighborhood and their homeowners to take action? How do you create a zero energy neighborhood? Are the existing technological solutions sufficient? Is the business case for such a transition feasible? What kind of process is needed? The University of Applied Sciences set up a dedicated educational element to address such questions in a novel way. An annual battle between multi-disciplinary groups of students is organized with the key assignment to construct the best action plan, which addresses the technical, economic and social issues related to tempting all stakeholders of a neighborhood to take action. This battle was held for the first time in 2014, for the neighborhood 'Oranjekwartier' in IJsselstein. In this paper the outcome and impact of the battle will be addressed, on neighborhood, stakeholders and students alike. Moreover an analysis of the advantages and disadvantages of the educational tool 'student-battle' will be shown, in the light of multi issue, multi actor challenges and related societal challenges such as energy transition.

1 Introduction

The use of fossil fuels and the emissions of greenhouse gasses must decrease in order to limit the severe impacts of climate change. In the Climate Change 2014 Synthesis report (IPCC) a relation is found between the production of greenhouse gasses and climate change, as land and ocean surface temperatures and sea levels are changing. In figure 1 this relation is given.

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It is clear that the growth of greenhouse gasses has a relation with climate change. To reduce or stop climate change, the production of greenhouse gasses must be decreased. The production of greenhouse gasses is related to the use of fossil fuels. Energy is used for industry, households, traffic and transportation. Figure 2 shows the primary energy use per sector. In 2013 13% of the energy use is for households. The charts are based on figures of Central Plan Office of the Netherlands (CBS, 2016)

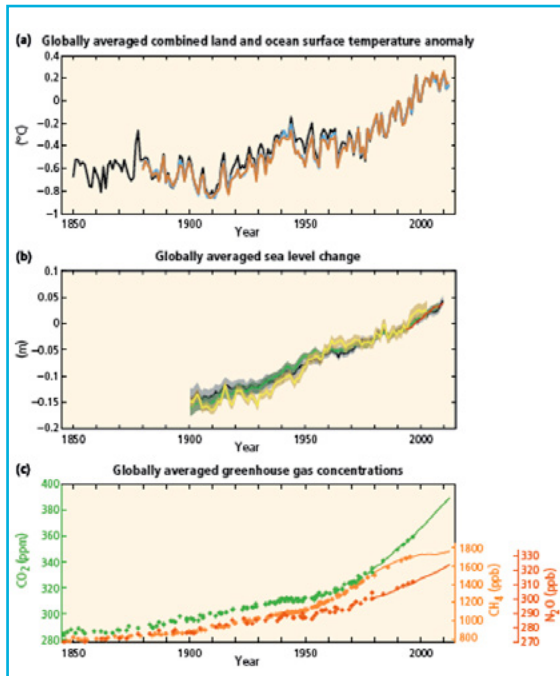


Figure 1: Climate change and greenhouse gasses (Pachauri, Meyer, & eds., 2014)

Households in the Netherlands use a lot of fossil fuels for their building related energy demands such as heating and cooling, which needs to be decreased in order to achieve net energy neutral housing. The goal of the Dutch government is to realize the transition to an energy-neutral environment because of the climate change and the independency of energy import from other countries. An energy-neutral neighborhood means that all the energy that is used by the neighborhood during a year, will be produced in the neighborhood by sustainable energy systems like solar panels, wind turbines, etc. To accelerate this transition, the government wants to transform existing buildings to net energy neutral. This means that the amount of energy required both for the building itself and for household use is produced by the building itself throughout the whole year. The question is how this

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can be achieved in a technically, economically and socially feasible way. The houses are either owned by the residents themselves, by public housing corporations or by private real estate owners. All these actors shall be involved in the realization of the energy transition. Not all buildings are suitable to become energy neutral and energy is also required for the urban space. This energy must be produced within the neighborhood, e.g. in public spaces or on public buildings. The question is who the stakeholders are in this neighborhood and how the municipality can organize this transition with involvement of the various stakeholders.

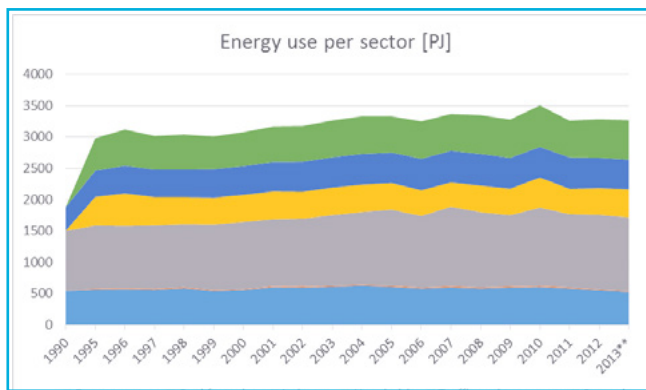


Figure 2: Energy use per sector (CBS, 2016)

The University of Applied Sciences Utrecht set up a dedicated educational element to address such questions in a novel way. A yearly battle between multi-disciplinary student groups is organized with the key assignment to construct the best action plan to encourage all stakeholders in the neighborhood to take action. The action plan should address the technical, economic and social issues related to the acceleration of the transition towards an energy neutral environment. The students will develop this action plan in cooperation with the municipality and the stakeholders in that neighborhood.

2 The assignment

In 2014 the University of Applied Sciences started with the battle as a multi-disciplinary project for fourth year students of the built environment. There were two groups of eight student which have done research for the municipality IJsselstein. In one group there were two students Urban Planning, three students Real Estate from the Netherlands, two students Real Estate form Turku Finland and one Architecture

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student from Valencia Spain. In the other group there were two Urban Planning students, two Architecture students and three Real Estate students all of whom were Dutch.

The key research question of the assignment was as follows:

"How can the neighborhood "Oranje Kwartier" be transformed into a net energy neutral residential area? Develop an action plan in order to achieve this within 20 years."

This meant that in this plan different interventions on different scales were defined for the different stakeholders involved. (E.g. interventions on the scale of a single house by the residents and interventions on a neighborhood scale by the municipality.)

For the plans they made, it was important to describe the way people can be motivated to change their own home or public space into a zero energy house or environment. Earlier experiences from the client "Natuur en Milieu Utrecht" or Nature and Environment federation Utrecht" and the Municipality IJsselstein showed that home-owners were not so easy to convince to invest in energy saving. This plan had to convince all the stakeholders that zero energy is feasible. Therefore technical as well as financial solutions were required.

The unique point of this project was the time frame. Most of the time the energy saving projects never reach farther than the planning stage because public funding is too limited, both in time and money, and the Municipality has no influence after the sale of the ground to third parties. For this reason they asked for an action plan to get a zero energy neighborhood in 20 years. It was important that the home-owners were involved in the plans. And incentives for all stakeholders in the region had to be found to participate in the project.

The research was concluded with a report in which recommendations and possible solutions for reaching a net energy neutral neighborhood within the next 20 years were described. These recommendations also involved the creation of incentives for all stakeholders involved to join the initiative. Students from different fields of education were involved in the project. The proposed solutions consisted of different scenarios. At the end of the project, the two project groups presented their plans in a battle in the local neighborhood school to the residents of the neighborhood. A jury consisting of Lectors, a project manager, the foundation "Natuur en Milieu" and

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Councilor of IJsselstein, evaluated these presentations. The jury selected one of the proposals as the winner. The winners presented their plan again to the municipality of IJsselstein.



Figure 3: Changes of the neighborhood (picture of the presentation)

In 2015 there was a new battle. This time it was the same casus but now for the neighborhood Lunetten Hoograven in Utrecht. And the student groups were now multi-disciplinary, covering more fields of study like logistics, built environment, mechanical engineering and technical management. This time there were foreign students in both groups from Turku Finland and Valencia Spain. The battle was now part of a minor program and no longer a regular project. That provided the University of Applied Science with the opportunity to provide a larger program of dedicated lessons about sustainability and more students from other disciplines could take place in the project. However, the place of this minor within the bachelor program was in the beginning of the third year, hence the knowledge level of students involved at the start was less than the year before.

3 Organisation of the project

The University of Applied Sciences Utrecht and the client created an alternative learning environment consisting of two groups who worked in teams in different classrooms. And they had access to the neighborhood and the municipality.

Normally the students would have done desk research for the needs of the people. However, in this course they visited the neighborhood and did a survey. They also interviewed all stakeholders to get more information on the intrinsic motivation of the people from that neighborhood. In the neighborhood IJsselstein the students

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only did a survey. In the neighborhood Lunetten Hoograven they were also attending neighborhood meetings about sustainability. For those meetings they built a barometer to show the urgency of changing the use of energy. This was their first contact with the people of the neighborhood. After that they also did a survey, they had more than 100 reactions on an online survey.

Houses	Build	Survey	Percent
Terraced house	168	24	14%
Apartment	84	0	0%
Semidetached house	53	9	17%
Detached house	15	4	27%
	320	37	12%

Table 1:
Number of buildings
and surveys of
Oranjekwartier
(Spitsbaard, et al.,
Statistische Analyse
Wijk Oranjekwartier
IJsselstein, 2015)

After this survey they could define the problem and had hundreds of idea's originating from all stakeholders.

Choices had to be made from all those ideas to find a feasible solution. This was done together with the client and the outcome was presented to the residents. Because there were two groups of students in the battle, there were two different proposals for an action plan. At the midterm review the plans were presented only to the client and the experts. During this midterm review one group decided not to present their solution because it was a battle. This meant they could not learn from each other. After the midterm review they worked out one scenario.

Both groups presented the proposal in the form of a battle, while the jury consisted of residents and professionals.

The jury's criteria were based on 6 points:

- Technical (is it feasible and is it energy neutral)
- Business case (is it economically feasible)
- Communication (is it clear what needs to be done)

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- Stakeholders management (is it clear for every stakeholder what needs to be done)
- Process (what are the actions)
- Integral solution (do the technical, economic and social parts come together in the solution)

The group with the best overall proposal won the battle.

The prize was that the student group was allowed to present their plan at the council meeting in IJsselstein. During this presentation there were a lot of councilors present and they took notice of the opportunities for energy saving and sustainable energy production in their own cities.

4 The experience in practice

Two groups have been working on an action plan in IJsselstein for Oranjekwartier. As mentioned the students started with a survey. The main conclusions of the survey from IJsselstein were:

- Older people have invested a lot in insulation, double glazing and new installations
- People want clarity about the business case; how much is the energy saving and what are the costs
- People want a clear plan and an information evening about possibilities and the feasibility

This was the input for their action plan.

In this action plan technical solutions were described, but the most important part was a process plan. The first question was how to make a zero energy neighborhood. This involves the techniques that make this possible. Solutions were given for building renovations. Technically you can realize net energy neutral houses with available technologies. They used the examples from platform 31 and building company BAM, Ballast and Volkerwessel Stevin. However, the financial feasibility of this renovation was a problem.

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The winning group developed a proposal with different steps in their plan. They started with the re-engineering of a part of the neighborhood where they proposed to build energy neutral buildings and an energy producing playground (with toys producing energy when being played with). Subsequently they looked for an energy ambassador who would change his house to a net energy neutral building as an example. In order to propagate the developed solutions the ambassador would let other people come to visit his or her house.

The municipality should lead the way by developing a part of the area with net energy neutral or energy producing houses as an example for the rest of the neighborhood. In this way the municipality could educate children about sustainable energy. The municipality could also develop more sustainable urban lighting.

Another part of the plan was to put solar panels on the gym for the urban energy use, but also to compensate for households that could not achieve net energy neutral. These households could then buy the renewable energy from the gym. The energy production should be implemented by founding a local energy cooperation within the neighborhood. The profits of this local energy cooperation could be re-invested in energy saving projects. (e.g. creating revolving funds.) To set up a local energy cooperation, a community in that neighborhood was needed. The student teams proposed to generate this kind of community first.

The community had to be prepared to invest in sustainable energy systems together, so the residents of the neighborhood could be the owners of the local energy cooperation and make their neighborhood more sustainable.

The process and the ideas that came out of the action plan were new and inspiring for the municipality and the people in the neighborhood. The municipality asked the students to give a presentation for the city council. The people there noticed that they could make changes to realize energy saving in their municipality. They have incorporated parts of the action plan in their policy letters.

5 Validation

Looking at the main question and sub questions and the outcome of the student projects, you can see a transition is possible if everyone involved is willing to participate it and the municipality and financial markets are prepared to contribute.

How the different stakeholders experienced the project was evaluated by a survey to everyone involved.

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For the municipality the project led to more knowledge about sustainability and net energy neutral renovations. They have used this knowledge in the different policy letters.

The municipality has taken part in this process and has concluded that there is still a lot of work to do. Their role is not to subsidize the projects but to lead by example and make decisions on how to integrate sustainability in their policies. The process of starting a good example project in that neighborhood has not yet started. So far, a year after this project finished, nothing has been realized in that specific neighborhood yet.

One of the stakeholders at that time was the foundation "Natuur en Milieu Utrecht", an organization to stimulate energy savings projects by municipalities. They were very pleased with the results of the survey. They learned that the energy saving was no trigger for people. They also liked to work with students because they are the new professionals of the future. And they have seen the change in the way of thinking by these students. In the beginning they were thinking more towards a technical solution and at the end a process solution with involvement of all stakeholders in the neighborhood was proposed.

For the students it was a new project with a real neighborhood and client. The close relation to reality made this project particularly interesting. The students liked to participate and indicate that they have learned a lot. They claim to have learned the most from the survey, the wishes of the people and the peoples' questions. They didn't realize beforehand that not everyone is interested in energy saving and that some people don't have the knowledge how to save energy. Some of the student concluded at the end of the project that they had research questions left, and decided to do their bachelor thesis on topics related to this project.

Two students did research on 'net energy neutral' renovation concepts for buildings in that neighborhood. Another student did research on energy saving in urban space, looking at the lighting, green and the urban energy use.

The student groups enjoyed the battle as well. This gave them an extra motivation to produce a better product. They wanted to win this project. The winner got to give a presentation to the city council. They experienced this as a nice thing to do and a great experience.

The teachers also liked the project but they realized that it's not enough to have only students from the institute for the built environment. More disciplines are required, like mechanical engineering and communication. Also they felt a lack of connection with the neighborhood. There was no ambassador at the end of the project to help the municipality to realize the project, and make a start with the action plan.

6 Conclusions and further research

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6.1 Results of the project

The result of the project shows that it is possible to achieve a transition to net energy neutral houses and neighborhoods when the action plan developed by the students is implemented. In order to get the neighborhood and all stakeholders to take action, crucial steps have been defined in the action plan amongst which the appointment of an ambassador and the municipality taking the lead.

These are mainly process steps, the technological solutions that are currently available are more than sufficient to achieve a net energy neutral neighborhood. However, for individual houses this is not always the case.

The economic feasibility depends upon local stakeholders being prepared to invest and upon a collective approach within the neighborhood, hence founding a local energy cooperation.

As described in the action plan the required process focuses mainly on convincing people, with communication, examples, events and ambassadors.

6.2 Student battle as an educational tool

The outcome of the battle for the students proved to be both positive and negative. On the positive side, the students learnt to actively participate in a multidisciplinary team and learnt to deal with real stakeholders and clients. This provided them with a direct connection between the knowledge they acquired and the everyday practice. The competition element gave them the incentive to put their best effort in the development of the action plans.

The downside of a competition is the lack of cooperation between the two student teams. The knowledge is hardly shared between them, missing opportunities to even further enrich the students insight in the issues they face when it comes to actually implementing a strategy to realize a net energy neutral neighborhood.

For the stakeholders involved, the battle proved to be a useful tool to select the best strategy. The fact that they had something to choose positively influenced their involvement. Otherwise they said also that the best solution would be a combination of the solution of both parts.

For the teachers, the battle made clear that more fields of expertise should be involved. Especially the communication part is missing. The input from stakeholders and residents from the neighborhood proved to be a valuable addition to the education within the minor. This also applies in particular to the survey, from which the students learned a lot about the incentives people have regarding energy saving.

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For further development of the battle, it is important that there will be a more multidisciplinary group of students with, as mentioned, at least a student specialized in communication but also in finance and psychology. Also there must be a tutor with expertise in communication, finance and psychology.

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THEME 4 CIRCULAR PROCESSES: MODELS & MATERIALS, CONSTRUCTION CHAINS, ECO-MATERIALS AND EMBEDDED ENERGY



It is clear that the linear approach to our economy has its limitations and that apart from the energy crisis, the resources problem is an even greater concern. This session intends to investigate the changes of circular processes in urban transition and refurbishment. Again tangible examples of successful business models are welcome. Moreover, we will investigate flexible models, construction chains and materials.

- a. Modular refurbishment concepts apt to adapt future developments
- b. Bio-based material and building construction chains
- c. Impact of large scale refurbishment on local environment
- d. Embodied energy & eco-materials to optimise facade renovations

IDENTIFYING THE BUSINESS VALUE OF A CIRCULAR ECONOMY ON A MICRO-LEVEL ANALYSIS THROUGH REAL OPTION REASONING

In this study, the added value of real option valuation (ROV) is considered within the context of a circular economy. The aim of this research is to make an initial and general scoping of the value of real options within circular business models. Based on this research, there is no reason to believe that, from a real option perspective, the value of a circular business model is in general significantly larger than the value of a linear business model. Hence, there are likely also other dimensions of business value that cause companies to operate in a circular manner. However, ROV should not be presumed valueless, as six out of nine case study companies in this research are likely to benefit from ROV. The initial conceptual model that constitutes this research is updated according to the conclusions from this study. The new model will be used as the basis for further qualitative or quantitative research, in order to establish a more specific and externally valid result. All circular processes are within the scope of the research. The focus on all processes is to put the question of valuation of these processes in perspective.*

1 Introduction

In general, our economic system is considered to be open-ended (Andersen, 2007). Companies extract materials to manufacture a product and sell this product to the consumer. The consumer discards the product when it no longer serves its purpose. It has now become waste. In the literature, this linear pattern is often referred to as the 'take-make-dispose' pattern (Ellen MacArthur, 2013). A simplified open-ended economy is depicted in figure 1.

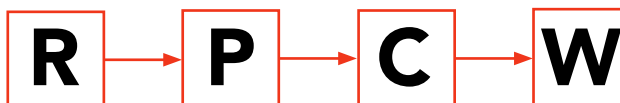


Figure 1: The linear business model. **R** Resources, **P** Product, **C** Consumption, **W** Waste

* Companies in 11 Dutch industries have been researched. More research is currently conducted

The circular economy (CE) offers a solution for sustainable growth in a world of volatile resource prices (Preston, 2012). There is not one single definition of CE in the literature. The CE is intended to be restorative: the circular or closed flow of materials and the efficient use of durable raw materials and renewable energy are at the heart of the CE (Yuan et al., 2006; Park et al., 2010; Ellen MacArthur, 2013; Aldersgate, 2012).

If one wants to successfully implement a CE, it will be the businesses that need to adopt a circular business model. In order to evoke a transition to the CE, it is necessary to prove that at least the same business value can be created in circular business models. In the academic literature, business value creation in the CE nevertheless remains relatively underexposed. When stakeholders would recognize that environmental and social behaviour could also be financially beneficial, it will become easier to convince companies to adopt circular economic practices (Hoffman and Bazerman, 2005).

This study contributes to the existing literature on the business value of the CE by scoping the added value of a circular business model from a real option perspective. This is done by means of a qualitative analysis of the real options obtained by companies in CE priority sectors. The corresponding research question of this research is: *Is the value of a circular business model larger than the value of a linear business model for companies in circular economy priority sectors on a micro-level of analysis in terms of real option reasoning?*

Based on this research there is no reason to believe that, from a real option perspective, the value of a circular business model is in general significantly larger than the value of a linear business model. Hence, it appears as if there are potentially also other dimensions of business value that cause companies to employ a circular business model. ROV should however not be presumed valueless as it is scoped to be of added value for six out of nine case study companies in this research. The conceptual model that formed the basis for this research has been updated according to the conclusions of this research. The new model can serve as the basis for further qualitative or quantitative research, in order to establish a more specific and externally valid result.

2 Conceptual model

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In this section, a conceptual model is discussed. It approaches the business value of the circular economy from a real option perspective. This conceptual model should be seen as an addition to the various business value opportunities discussed in the literature review.

Imagine a company that currently offers its products to its customers in a linear business model:

- The company produces a product
- The company sells the product to a consumer, who becomes the owner of the product
- The consumer consumes the product until the product reaches its end-of-life (EOL)
- The consumer has the option to sell or dispose the product, or parts of it

The company could make an investment that allows it to offer its products in a circular business model:

- The company produces a product
- The company sells the performance of the product to the user while it retains ownership over the product
- The user uses the product until the product reaches its EOL. The company meanwhile ideally acts as a service provider
- The company receives the product back from the user
- The company has the option to for example reuse or recycle the product, or parts of it

The difference between the two scenarios is that the customer consumes the product in the linear approach while it uses the product in the circular scenario. The latter type of sale is called a performance-based contract: you pay for performance rather

than ownership. (E.g. from the research is Philips Lightning: At Schiphol the company is responsible for the light, the ownerships/the performance stays in the hands of Philips). The benefit of performance-based contracts is that the company is ensured to receive the product back. This creates an incentive for the company to optimally design the product at its beginning-of-life (BOL), perform maintenance when necessary throughout its middle-of-life (MOL), in order to maximize the product its value at its EOL. A rational manager will always choose for a circular business model when it offers greater value than a linear business model. In other words, a circular business model is an attractive option when a company is able to maximize the value of the different options at its EOL.

3 The value of a circular business model

Let us illustrate this in a theoretical example. Imagine a company that produces one product with economic lifespan* [T]. When this company employs a linear business model, the company sells the product for price [P]. The added value for the company is $\{P - C\}$; the selling price minus the cost price. The EOL value for the consumer is scrap value [S].

When the company would employ a circular business model, the product, or parts of it, can become (more) valuable at its EOL. This is because the company now has an incentive to maximize the EOL value of the product at its BOL and throughout its MOL. In order to establish a circular business model, a company potentially has to make substantial investments [I] in the product or across the supply chain. This can be a singular investment or (the present value of) a raise in cost price [C]. Since the user does not physically own the product anymore in a circular business model, the company has to compensate the user for scrap value [S].

In return for [I] and [S], the company creates dimensions of business value as discussed in the literature review. These six pillars of business value are captured by [BV]. It is important to note that you will always incur [BV], regardless of any choice you make.

So far, nothing is new. However, with a circular business model, the company also creates a set of options. Options are rights, not obligations; unlike [BV] you do not incur them regardless of the choices you make. In my view, there are two sorts of options granted in a circular business model; options that concern the product and options that concern the strategy. The total set of both product- and strategic options is referred to as [O] for simplicity.

* *The economic lifespan of a product is the period for which a product is useful to an average owner. This should not be confused with technical lifespan, or the actual physical lifespan of an asset*

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Based on the literature review and discussions with the expert panel, the following **product options** arise in a circular business model:

- The option to *reuse* the product, or parts of it
- The option to *refurbish* the product, or parts of it
- The option to *remanufacture* the product, or parts of it
- The option to *store* the product, or parts of it
- The option to *recycle* the product, or parts of it

Based on the literature review and discussions with my expert panel, thereby, one potential **strategic option** is identified. This is the option to use the circular business model for marketing purposes. Practical research should prove whether more strategic options exist in circular business models.

For simplicity, now assume that the present value of the cash flows [V] is equal in both the linear and the circular business model. In other words, the selling price and the quantity sold remain equal in both models. In that case, the benefit from a circular business model is the present value of all circular business value dimensions [BV], plus the value of all options [O]. This benefit comes at the cost of investment [I], plus the compensation for scrap value [S].

The company can now determine whether $\{O + BV\}$ is larger than $\{I + S\}$. If so, a circular business model is of added value in comparison to a linear business model.

The options [O] that the company creates with its circular business model are examples of real options. Commonly, investment decisions are evaluated using a discounted cash flow (DCF) analysis. However, the DCF method is limited in the incorporation of uncertainty and managerial flexibility. Real option valuation is much better capable of handling uncertainty and offers managerial operating flexibility and strategic adaptability in a constantly changing and uncertain world (Trigeorgis, 1996).

The options [O] in a circular business model can be valued with ROV. Suppose a company considers switching to a circular business model by using a different (potentially more expensive) commodity that does not wear and is hence more valuable at EOL. In this case, the company makes an investment [I]: the present value of the difference in costs between using the circular commodity and the linear commodity. In exchange, the company receives product- and strategic options [O].

The value of [O] is dependent on economic lifespan [T]. This is the point after which the product is returned and an option can be executed. Thereby, the value of [O] is also dependent on a considerable amount of volatilities [σ] in corporate decision-making. An example is the volatility of commodity prices. When [σ] is high and [T] is long, there is a higher probability that the commodity price is high. Hence, the option to, for example, reuse your materials is valuable. Remember that reusing is an option, not an obligation; hence, you do not incur the downside risk.

Besides the volatility of commodity prices in the example above, potentially more volatilities are relevant. Together with my expert panel, I have made an initial scoping of these relevant volatilities:

- Volatility of commodity prices
- Volatility of labour costs
- Volatility of energy costs
- Volatility of scarcity of commodities (both physical and geo-political)
- Volatility of technology *
- Volatility of demand **
- Volatility of feedstock volume ***
- Volatility of regulation

* E.g. current technology, materials, or production processes becoming outdated

** E.g. due to a change in consumer preferences or competition

*** The feedstock volume indicates how much of your products are actually returned

These volatilities are presumed relevant when a change in the respective variable poses a relevant risk to the company's operations. One should note that the aforementioned volatilities are indicative, not generalizable, and do need further research.

In a circular business model, the company is likely to create circular business value [BV]. The different dimensions of [BV] can be found in the literature review. Thereby, the company also potentially creates a set of real options [O]. The value of [O] is dependent on $[\sigma]$ and $[T]$. For simplicity, we assume that cash flow $[V]$ is equal in a linear- and circular business model. A rational manager will then prefer a circular business model to a linear business model when $\{O + BV\}$ is larger than $\{I + S\}$.

It is important to properly identify and value the real options created in order to establish whether a circular business model brings additional business value. When one does not recognize or properly value the options created in a circular business model, it could well be that the CE will unjustifiably be seen as unprofitable.

In order to underpin this conceptual framework, the theory should be applied in practice at companies that operate a circular business model. In the next section, the methodology to do so will be elaborated upon.

4 Results

The results are briefly presented in a cross-sectional overview with the results from all case study companies. The column is divided into three parts: 1) relevant volatilities, 2) product options, and 3) the strategic option. An '●' indicates that the volatility has been scoped as relevant or that the corresponding real option is present. For companies with an asterisk, ROV has been scoped as valuable based on the individual case study.

The bottom row of the table shows the total percentage presence of the corresponding volatility or real option. Note that given 11.1% significance level, a presence above 88.9% indicates a significant result, as discussed in chapter four. Accepting a hypothesis implies that the corresponding item is significantly relevant. It does however not imply that the corresponding result is also externally valid. Given the variety of the data set, a significant result is more an indication that the result is likely to also uphold for circular business models in other industries. See next page.

	I - Relevant volatilities								II - Product options					III Strategic option	
	Risk of changing commodity prices	Risk of changing labour costs	Risk of changing energy costs	Risk of changing scarcity of commodities	Risk of changing technology	Risk of changing demand	Risk of changing feedstock volume	Risk of changing regulation	Option to reuse	Option to refurbish	Option to remanufacture	Option to recycle	Option to store	Option to waste for energy	Option to use CE for marketing purposes
Verosol*	•			•	•	•	•			•	•	•			•
Royal Philips N.V.				•	•	•			•	•	•	•			•
Generator City*	•				•	•		•	•	•	•	•			•
BMA Ergonomics						•	•		•	•	•				•
Dutch aWEARness*	•			•	•	•						•			
Interface				•		•	•		•			•		•	•
Delta Development*	•			•		•			•	•	•	•			
Dura Vermeer*	•		•	•	•	•		•				•			
Royal HaskoningDHV*	•			•		•		•			•	•			•
Total percentage	67%	0%	11%	78%	56%	100%	33%	33%	44%	56%	67%	100%	0%	11%	67%

The question: *What are the product options for a company with a circular business model?* There has been at least one product option created in every circular business model. This implies that the employment of a circular business model is likely to grant a company at least one product option.

The question: *What are the strategic options for a company with a circular business model?* In six out of nine cases there has been one strategic option created. This

implies that, based on this research, there is no reason to believe that a circular business model is likely to grant a company at least one strategic option.

The question: *What are relevant volatilities for companies with a circular business model?* In the table can be observed that the volatility of demand is the only variable that has been identified as relevant by every interviewee. This implies that, based on this research, there is reason to believe that volatility of demand is likely to be relevant in a circular business model.

5 Conclusions

The aim of this research is to assess whether ROV is of added value in the identification of business value in a circular business model. In this study, the theory from this conceptual model has been tested for practical relevance in an empirical setting. The conceptual model makes a preliminary description of the different real options that are likely to be scoped within circular business models. Thereby, the different volatilities that are likely to determine the value of these options are also described. To test the conceptual model in practice, qualitative data is collected. This is done through face-to-face interviews at nine companies that operate a circular business model, in sectors that are scoped with priority for the circular economy. The results are presented in a case study that contains nine single-case analyses and one cross-case analysis. Based on these results, conclusions are drawn on whether ROV is of added value in circular business models.

At every case study company, at least one *product option* has been scoped. Based on this research, there is however no reason to believe that there are *strategic options* created in every circular business model. The product option to recycle is the only option that is significant, as it is scoped at every case study company. The option to store, which was preliminarily believed to be present, is not scoped in any of the cases. The option to waste for energy had not been preliminarily scoped, but can be an interesting addition to the conceptual model.

While there are product options present, the volatilities that underlie option value are not always considered to be relevant by every case study company. In other words, future decisions are not always influenced by the development of the uncertain variables that cause the options to have value. If so, ROV is of no added value, as you do not value the right to wait and see how the future develops. The only volatility that has been found to be significant is the risk of an unexpected change in demand. This is rather remarkable as the urge for the CE is mainly supported by a threat of

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resource scarcity. The risk of an unexpected change in raw material prices or -scarcity does not appear to be relevant for every company that employs a circular business model. This gives reason to believe that there are other dimensions of business value in a circular business model that cause companies to operate in a circular manner.

The main conclusion from this study is that ROV is of added value in six out of nine single-case analyses. Given a significance level of 11.1%, there is therefore no evidence that the business value of a circular business model is larger than the business value of a linear business model from a real option perspective. In other words, real option reasoning does not add value for every company with a circular business model.

Even though ROV does not add value in every circular business model, there are still six companies for which it is likely to be of added value. One should note that the dataset of the companies in this study is very diverse. Future qualitative research could thus potentially still find externally valid results, but then for a more specific set of company characteristics. Based on this research ROV is likely to be valuable for products that have a high resource density and for which the volatility of raw material prices and -scarcity is relevant in their decision making. Furthermore, modularity of products is likely to be positively correlated with the amount of real options created. In combination with modularity, indicated relevance of volatility of technology or regulation also increases option value. Hence, ROV could be of added value for industries that possess the previous characteristics.

While this research does not provide significant evidence to believe that, from a real option perspective, the value of a circular business model is always larger than the value of a linear business model, the conceptual model has undeniably been improved. This new conceptual model can now serve as the basis for future, more narrowed, qualitative or quantitative research on the application of real option theory in circular business models.

6 Limitations and future research

6.1 Limitations

The qualitative nature of this research comes with a certain amount of limitations to conduct this research. This section discusses impact of the most relevant limitations on the quality of the research, the ability to answer the research question, and how this can be overcome in the future.

The largest limitation to this research is the lack of prior academic literature on the topic. Consequently, this study was designed as a scoping study to make an initial assessment of the different real options in circular business models and their underlying variables. Due to the broad nature of the research, the chance on an externally valid result is small. Based on this research, future research can limit itself to the areas that are presumably interesting for the application of ROV.

6.2 Future research

As this study is intended as a scoping study with the intention to lead the way for more research, understandably a great cause for further research is established. Throughout this study, this cause is already often highlighted. This section summarizes the main directions for future research.

The academic literature on the business value of the CE in general is very limited and deserves more attention. To the best of my knowledge, Park et al. (2010) are the only academic researchers to qualitatively describe business value creation in the CE. At least all these business value dimensions scoped in the literature on RL should also be tested in the context of the CE. It would be interesting to see, for example, to what extent the reuse of products has a cannibalizing effect on current sales. In addition, the inclusion of the innovation from employing a circular business model is an interesting direction that has not been studied in academic research.

Based on this research, these should be sectors with products that have a high material density. This is likely to increase the relevance of the underlying volatilities, and hence option value. Modular design in combination with changing technology or regulation is also likely to increase option value. This more narrowed direction of research could lead to an externally valid result for specific industries. Thereby the transport sector has not been researched. It is not likely that I would have scoped new options or volatilities when incorporating the transport sector. However, applying ROV would potentially be of value here because of high modularity, a high raw material density and a long economic lifespan [T]. In addition, I suspect the transport industry to assess the volatility of regulation and technology relevant. However, this is based on an educated conjecture.

The last interesting direction for future research would be to perform quantitative research to calculate the magnitude of the option value. Subsequently can be concluded whether the business value dimensions [BV] and the value of the real options [O] outweigh the investment [I] and the compensation in scrap value [S].

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Or, in a formula, whether $\{BV + O\} > \{I + S\}$. If so, the employment of a circular business model is of larger value than employing a linear business model. If $[O]$ is thereby larger than zero, one can conclude whether the application of ROV is actually of added value for the circular business model in question. This quantitative analysis should prevent a circular business model from incorrectly being seen as unprofitable.

In the coming year the students of the minor Circular Economy in the cloud will conduct further research in this field in companies not only in the Netherlands.

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TITLE
Identifying the business value of a circular economy on a micro-level analysis through real option reasoning

AUTHOR
Drs. P.C. Anker

CO-AUTHOR
Victor Keunen MBA

ORGANIZATION
University of Applied Sciences Rotterdam
Rotterdam, the Netherlands

MAIL ADDRESS
p.c.anker@hr.nl
tel. +31 6 30871253

victor.keunen@gmail.com

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TITLE

Circular hub: towards zero transport emission and zero construction and demolition waste on a local scale

AUTHOR

Dr.ir. Ruben Vrijhoef
Ir. Kitty Vreeswijk
Ir. Marjoke de Boer

ORGANIZATION

HU University
of Applied Sciences
Utrecht, the Netherlands

MAIL ADDRESS

ruben.vrijhoef@hu.nl
tel. +31 6 39251420
kitty.vreeswijk@hu.nl
marjoke.deboer@hu.nl

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CIRCULAR HUB: TOWARDS ZERO TRANSPORT EMISSION AND ZERO CONSTRUCTION AND DEMOLITION WASTE ON A LOCAL SCALE

From a circular standpoint it is interesting to reuse as much as possible construction and demolition waste (CDW) into new building projects. In most cases CDW will not be directly reusable and will need to be processed and stored first. In order to turn this into a successful business case CDW will need to be reused on a large scale. In this paper we present the concept of a centralized and coordinated location in the City of Utrecht where construction and demolition waste is collected, sorted, worked, stored for reuse, or shipped elsewhere for further processing in renewed materials. This has expected advantages for the amount of material reuse, financial advantages for firms and clients, generating employability in the logistics and processing of materials, optimizing the transport and distribution of materials through the city, and thus the reduction of emissions and congestion. In the paper we explore the local facility of a Circular Hub, and the potential effects on circular reuse, and other effects within the City of Utrecht.

Keywords: construction and demolition waste, hub, logistics, materials reuse, transportation emissions.

1 Introduction

The potential of the circular economy for the Dutch economy is estimated at an annual cost saving effect of 7.3 billion euros and job creation of 54,000 jobs (Bastein et al, 2013). However this potential needs to be used in applied solutions in often local settings such as cities. Cities are reliant on local development for their employment, business activity, and reduction of energy consumption, waste and air pollution in the city. In these areas cities feel more and more pressure and they set high ambitions.

The idea of the 'Circular Hub' focuses on minimizing unemployment, waste as well as greenhouse gas emissions of distribution and transport. Bundling, sorting and recycling construction and demolition waste (CDW) helps to reduce waste and transportation as a result. This contributes to the objectives of the City of Utrecht to become CO₂ neutral in 2030 (Gemeente Utrecht 2015). At the same time it can create jobs for low-skilled labor, and opportunities for creative companies and products that create new products with waste (Vrijhoef, 2015a).

2 Basic idea and importance of a hub for optimising construction logistics

In the last few years particularly cities have restrained the entering of polluting vehicles and improving the inner-city climate and air quality in general. Particularly construction transport is relevant to this aim while typically 30 to 40% of all transport is related to construction traditionally (Figure 1). This represents some 40% of vehicle emissions and road congestions. Governments and road users are keen to reduce this. While load factors of construction transport tend to remain structurally under 50%, in few cases down to 15% of their loading capacity a need to act is felt urgently (Vrijhoef 2015b).

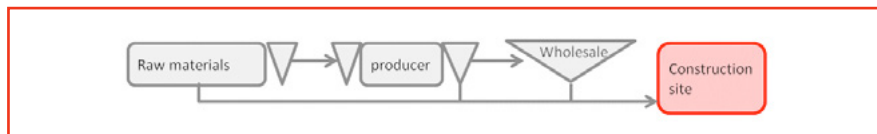


Figure 1: Traditional supply process to a construction site (Vrijhoef 2015b)

In the UK and notably London local government and the industry have shifted to action some years ago with demonstrable results applying 'hubs' or Construction Consolidation Centres (CCC) (Sullivan et al 2010). The London Construction Consolidation Centre (LCCC) claims that the number of construction vehicles entering the City of London, and delivering to the sites being served by the LCCC is reduced with 68% (Brett 2007), and also supplier journey times have been reduced two hours (MVA 2006). The delivery performance of goods delivered the first time right is 97% (Constructing Excellence 2007). LCCC claims that a reduction of materials waste is generated of up to 15% by reduced damages, less materials that are lost, and less theft (Transport and Travel 2010). Also reduction of materials and packaging on site are reported (Department for Transport 2007). As a result of the reduction in vehicles and movements, a reduction of greenhouse gas emissions has been reported of about 75% (Transport for London 2008).

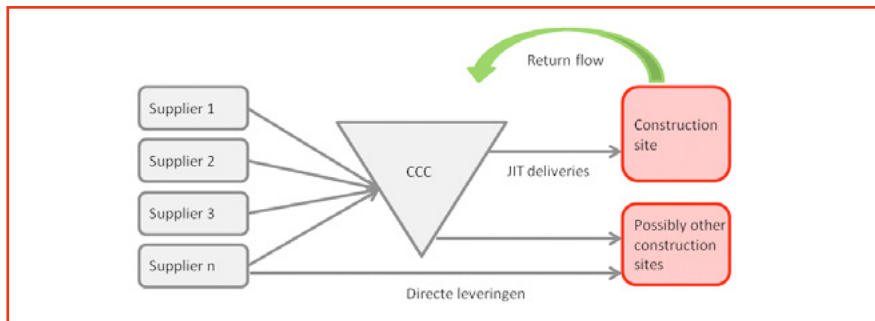


Figure 2: Supply and return flow of CDW using a hub i.e. CCC (Vrijhoef 2015b)

Decoupling the construction chain can be done by using a CCC i.e. a hub (Figure 2). The hub functions as a decoupling point between supplier and construction site. These centres function as hubs in a few cases already used in construction as a temporary storage at or near the construction site. The hub then functions as a decoupling point at which supplies to the hub are controlled in a 'push' way, while goods to the construction site from the hub are supplied based on the project planning, based on the real and actual need and so controlled in a 'pull' way. There is also a possibility that goods are shipped from the hub, where the hub is used as a crossdock. By organizing the supply in this way the supplies are more time-independent than deliveries that are directly shipped to the construction site traditionally.

Besides multiple sites can be serviced by the same hub. To conclude, a hub can also handle return flows from the construction site including recycling of debris, packaging and equipment. Studies in different local settings show that applying reverse logistics techniques should reduce empty runs up to about 35%, and about 40% of all vehicles leaving construction sites should be fully loaded with CDA (Shakantu 2008).

3 Opportunities of reusing construction and demolition waste

In general in the Netherlands approximately 40% of all raw material flows are related to building and construction. Reusing CDW is no new phenomenon in the construction industry. Already some three decades ago the urgency for reuse increased by the great demands for building materials. However compared to that time, currently technical possibilities to separate and reprocess CDW to be reused in new projects have increased dramatically. The demolishment in itself will cost extra labour (estimated 10%) and costs for control and compliance, but this is compensated by higher revenues of raw materials and preventing dumping costs (Cramer 2015).

Below is a list of different materials where dumping costs in the case of Utrecht have been compared to the revenues that could be gained in the case of reuse (Table 1). Any processing costs are not included in this study and there is no account yet of the transportation costs (Derksen et al 2015).

Materials	Costs of dumping (euro)	Revenues of reusing (euro)
Bricks per piece	0.015	0.60
Cement per kg	0.010	0.20
Roof tiles per piece	0.025	0.15
Wooden frames per piece	30.00	200.00
Plastic frames per piece	55.00	150.00
Wooden door per piece	30.00	200.00
Plastic door per piece	55.00	400.00

Table 1: Comparison of the costs of dumping CDW versus the revenues of reusing CDW.

Revenues estimated based on market prices of equivalent new materials (Derksen et al 2015)

On a local scale one could enlarge the amounts and scale of reusing CDW, and improve the business case, particularly if the creation of local labour is included to process and distribute CDW to be reused.

However there is no networked facility to reprocess and reuse CDW on a large scale. In addition storing and reselling renewed construction material and components should be supported at a local or regional level. This would enable a platform for the supply and demand of reused construction material and components. Preferably supply and demand would meet 'just in time' (Cramer 2015). However in practice, it is to be expected that decoupling supply and demand would be needed via facilities such as a hub.

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3.1 Demand for construction and demolition waste

For the City of Utrecht the business case was studied applied to housing. For ten housing projects with a prospected number of around 10,000 houses to be built in Utrecht the potential demand for CDW and interests of stakeholders were analysed (Figure 3). This analysis has shown that many construction projects had already started and therefore it is difficult to engage these projects for the circular hub. The selection for projects potentially interesting was driven by their start data from January 2016. Furthermore, in most cases the City of Utrecht is the main client or stakeholder which enables sustainability ambitions to reuse CDW and grasp the additional benefits of reuse. Therefore, the circular hub may also be included more easily (Derksen et al 2015).



Figure 3: Potential projects demanding reused CDW in Utrecht in 2016 and 2017 (Derksen et al 2015)

3.2 Supply of construction and demolition waste

On the other hand, an analysis has taken place in the potential supply of CDW and materials from different demolitions in Utrecht in order to be able to satisfy the amounts of materials demanded. A materials category selection has taken place to identify the materials that are available at a certain moment. It appeared difficult though to anticipate the planning of demolition projects and orderly ways of recovering CDW and reusable building materials.

Particular interest was for buildings of about the same age and their possibility to use large quantities of the same raw materials from the demand and supply side. For instance using materials from one project to the other in case of renovations. To determine which raw materials, materials and products are of interest, information

and data from various sources have been collected and studied, including databases such as Funda*. The materials studied included amongst others: Inner walls, floors, doors, tiles, window and door frames, plumbing and installations.

The analysis of the supply of CDW included coping with variants in the amounts supplied. Surplus of CDW that cannot be used directly could either be distributed through other channels, aims or locations, or taken in stock. The first option is to store goods and materials. On the basis of the capacity of the storage location, this can be sustained for a relative short period of time. When the demand for building materials remains smaller than the supply of demolition, saving materials will be no economical option. In addition it is interesting to approach users of CDW outside the construction industry, such as alternative sectors and furniture sectors (Derksen et al 2015).

3.3 Business case for reusing construction and demolition waste

The potential of demand and supply of CDW was analysed with a business case between a 'supply project' and a 'demand project' from the above analyses. To calculate the business case, the CDW from the demolition of a house in a supply project was projected on the design of another house in a demand project. The demand site is chosen based on planned construction projects. The demolition site is chosen on the basis of year and geographical location. In this manner, the business case serves as a clear example of a financial and logistics case to merge supply and demand.

The assumption used for the business case was that the CDW from the house demolished in the supply project would be useful as materials needed for the construction of the house in the demand project (Table 2). The ideal case would be that the materials needed are equal in quantity and quality as the CDW. However in reality this is not the case and often the materials are defective or damaged, and require extra work to be made ready for reuse, implying labour costs of applying reused materials to rise 10%.

* *Online property portal used by real estate agents in the Netherlands to offer houses and commercial building*

Materials (selected)	Supply of CDW of a house demolition (address Arienslaan)	Demand of a selec- ted new-built house (address Alexander de Grotelaan)	Resulting stock
Roof tiles m ²	51.95	53.11	-1.16
Outer doors	6	2	4
Inner doors	9	10	-1
Sinks	3	3	0
Toilet bowls	2	1	1
Bath tubs	0	1	-1
Stairways	2	2	0

Table 2: Analysis between supply of reused (selected) materials from a virtual demolition versus the demand of a selected new-built project, and the stock between the two as a result (Derksen et al 2015)

The analysis of the supply and demand show different amounts of materials and thus this creates stock. Storage costs are not included in the business case. For the business case we propose three scenarios in order to compare:

Scenario 1: All materials are dumped

Scenario 2: All materials are reused

Scenario 3: Most materials are reused, and the rest is dumped

Calculation of the three scenarios showed preference for scenario 2 (table 3). For this scenario the circular hub is put in place. This means that all CDW that can be reused and require adaption goes via the circular hub. CDW that cannot be reused directly on the project is stored in the hub. In this way, the hub adds most value, while materials can be used for later projects and this saving procurement costs, processing on location provides employment, and storage costs can be kept to minimal levels.

	Costs (euro)	Revenues (euro)	Balance (euro)
Scenario 1: All materials are dumped	20,397.27	0	-20,397.27
Scenario 2: All materials are reused	1,710.71	20,843.65	19,132.94
Scenario 3: Most materials are reused, rest is dumped	2,994.87	18,937.25	15,942.38

Table 3: Analysis of the costs and revenues, and the balance as a result, in favour of scenario 2: reusing all CDW from the demolition in the new project (Derksen et al 2015)

4 City distribution of construction materials via the circular hub

The Circular Hub Utrecht is envisaged on the Werkspoorkwartier and Lage Weide. The aim is having a hub location for city distribution of renewed and reusable construction materials via technical services and workspace to recycle and upcycle CDW at the site, as well as distributing new materials entering the city and being distributed efficiently via the hub. The hub will also function as a central warehouse for inhabitants and firms in the city, ordering materials for private and professional purposes and building projects. The hub will be a central point for city distribution connected to many sites in the city (Figure 4). These connections are aimed at increasing the amounts of CDW through the hub and the amount of services to the city for multiple parties and multiple ambitions, and thus increasing the value and sustainability of the business case of the circular hub.

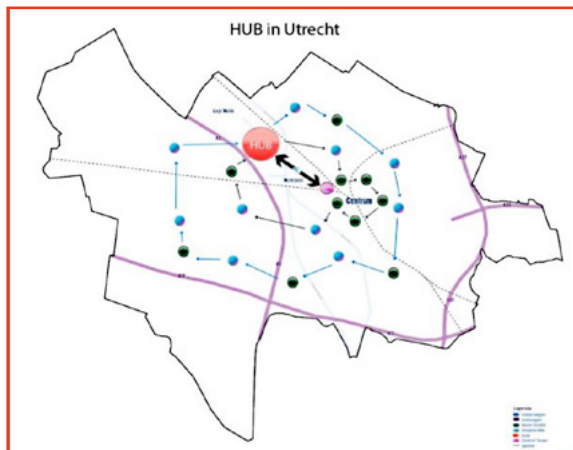


Figure 4: Circular hub connected to sites in Utrecht supplying and demanding re/upcycled CDW and construction materials (Roeven 2016)

The impact if the circular hub were applied has been studied on 5 conceivable increasing levels of development: Level 1, called 'Supply' would concentrate on demolition and transport to the HUB. It includes a role for a demolition company, transporter and supplier of new building material. While level 2 'Preparation' would also add services like ordering materials. Level 3 would concentrate on 'Material processing' including recycling and upcycling of CDW. Level 4 would represent 'Organizing' adding services including wholesales, warehousing, distribution to and from the hub, and logistics control. Level 5 would be the overarching 'Governance' structure which also includes applying rules and regulations, stakeholder communication, and anticipating future development of the hub. For each of these levels the potential savings and contributions have been assessed in case the hub would be applied, in terms of local employment, reduction of greenhouse gas emissions, process efficiency and profitability. An estimate of the contributions has not been feasible while indicators are lacking, although responses by local government and firms in Utrecht who were involved in the study indicated a potential (Roeven 2016).

5 Discussion

In this paper we explored the concept of the Circular Hub and the possibilities to implement this as a service with multiple contributions to the city of Utrecht. The application of a circular hub to create the needed facilities for urban distribution, logistics and technical services and workspace to recycle and upcycle CDW into renewed and reusable construction materials and components appears to be feasible on the location of the Werkspoorkwartier and Lage Weide.

Notwithstanding the potential benefits and applicability of the circular hub identified in this seminal paper, further research needs to be done in these directions. Particularly the redevelopment of the envisaged location of the hub in Utrecht, the development of hub services on the location, the creation of a viable business case for firms to use the hub, and the creation of employment for the city. The exact contribution of the hub and the possibility of ultimately reaching 'transition zero' on the three aspects of 'zero emissions', 'zero waste' and 'zero unemployment' are hard to assess on a local scale.

Potentially emissions of construction transport would eventually reduce to zero in case alternative power transmission for heavy freight were developed. Achieving zero waste would seem more practically feasible in the near future, while large amounts of CDW are already being recycled. However the challenge here is to increase the amount of 'upcycling' of materials. Modularisation and industrialization

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Circular hub: towards
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and zero construction
and demolition waste
on a local scale

AUTHOR
Dr.ir. Ruben Vrijhoef
Ir. Kitty Vreeswijk
Ir. Marjoke de Boer

ORGANIZATION
HU University
of Applied Sciences
Utrecht, the Netherlands

MAIL ADDRESS
ruben.vrijhoef@hu.nl
tel. +31 6 39251420
kitty.vreeswijk@hu.nl
marjoke.deboer@hu.nl

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of construction could have a positive influence here. To conclude, zero unemployment would depend on the amount of work the hub and additional facilities would generate, compared to the availability of skilled labour able to design and work with CDW, and the creation of jobs in materials logistics and additional facilities that the circular hub would offer and require.

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AUTHOR
Dr.ir. Ruben Vrijhoef

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ORGANIZATION
HU University
of Applied Sciences
Utrecht, the Netherlands

MAIL ADDRESS
ruben.vrijhoef@hu.nl
tel. +31 6 39251420
kitty.vreeswijk@hu.nl
marjoke.deboer@hu.nl

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A MORPHOLOGICAL DESIGN AND EVALUATION MODEL FOR THE DEVELOPMENT OF CIRCULAR FACADES

The current construction industry can be characterized by its linear model of material use resulting in waste with its possible negative impact on the environment and society. As a solution to the inefficient material use of the construction industry, they should strive to a circular model of material use. This can be obtained by the application of the circular economy concept. However, clear guidance on how to apply the circular economy concept in buildings is still to be fully developed. In this research, a Circular Building Framework (CBF) and a Morphological Design and Evaluation Model (MDEM) have been developed for the facade.

The CBF forms the starting point of the MDEM by providing a holistic view on all aspects related to the design and functioning of circular buildings. The MDEM forms a first draft to apply two essential principles 'design for disassembly' and 'design for adaptability' in the development of circular designed facades. In the MDEM two types of conceptual circular facade design solutions are identified making the facade designer aware about the consequences of different design decisions. The application of the MDEM will reclaim the embodied values of facade products by enabling them to enter re-life options at high quality.

Keywords: circular model of material use, conceptual circular facade design, disassembly, adaptability, circular economy

1 Introduction

The 20th century was a time of remarkable progress with steady economic growth, accompanied by an increase of resource consumption and a raising negative impact on the environment (UNEP, 2011). The dominating model in the past century can be characterized by its linear model of material use, following a 'take-make-dispose' pattern. All steps in this pattern involve resources, energy and labour, in which the last step leads to the destruction of applied energy and labour, creating enormous amounts of waste at the end of product life. This also accounts for the construction sector, in which the global extraction of construction mineral has grown by a factor 34,

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
A morphological design and evaluation model for the development of circular facades	ir. M.J.M. Bakx ir. M.J. Ritzen prof. dr. ir. J.J.N. Lichtenberg ir. P.R. Beurskens dr. ir. E. Durmisevic	Eindhoven University of Technology Eindhoven, the Netherlands University of Twente Enschede, the Netherlands	rene357@live.nl m.j.ritzen@tue.nl j.j.n.lichtenberg@tue.nl p.r.beurskens@utwente.nl e.durmisevic@utwente.nl

from 667 million tons in 1900 to 22,931 million tons in 2005 (Krausmann et al., 2009). This number emphasizes the need for a construction industry that is less material intensive.

1.1 Circular model of material use

The construction industry will probably become less material intensive, if they strive to a circular model of material use. There are already several concepts developed to create a circular model of material use (Boulding, 1966; Ellen MacArthur Foundation, 2013, McDonough & Braungart, 2002; Pearce & Turner, 1990). In this paper, the 'circular economy' concept as described by the Ellen Macarthur Foundation (2013) is selected as the starting point. The circular economy concept consists of a non-linear process, as opposed to our current way of material consumption and provides a model to close material loops in an economically attractive way (EMF, 2013).

In the current construction industry, clear guidelines on how to apply the concept of the 'circular economy' are still to be fully developed. Therefore, this paper presents the CBF, which provides the necessary guidance in the application of the circular economy concept in the construction industry. Due to the material inefficiency of the construction industry the emphasis of this paper will be the application of two essential building design principles, providing practical guidance for the transition towards a circular construction industry. To enable specific guidance the developed MDEM is specified towards the facade. This model seeks to remove the complexity of the application of the abstract 'circular economy' concept for facade designers by the provision of a model of understanding and evaluating their facade designs.

1.2 Circular Building Framework (CBF)

The CBF is developed to provide a holistic view on all aspects related to the design and functioning of buildings according to the circular economy concept (Figure 1), as identified in the 'design domain' and the 'construction domain'.

The 'design domain' consists of five circular building design principles that are abstracted from the initial circular economy principles (EMF, 2013) and specifically directed towards building design using the research of: Perez & Perez (2009), Douglas & Braungart (2010), Durmisevic (2006), Schmidt (2014), Akadiri & Olomolaiye (2012). Furthermore, the 'design domain' contains the 'circular building product levels' to provide a systematic view on how buildings in accordance to the circular economy concept should be perceived, designed and constructed, which is based on the research of: Durmisevic (2006), Eekhout (1997) and Brand (1994).

The 'construction domain' reveals how buildings according to the circular economy should function. This model is an adapted representation of the initial circular economy system diagram (EMF, 2013), which aims at removing its lack of focus to buildings and

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
A morphological design and evaluation model for the development of circular facades	ir. M.J.M. Bakx ir. M.J. Ritzen prof. dr. ir. J.J.N. Lichtenberg ir. P.R. Beurskens dr. ir. E. Durmisevic	Eindhoven University of Technology Eindhoven, the Netherlands University of Twente Enschede, the Netherlands	rene357@live.nl m.j.ritzen@tue.nl j.j.n.lichtenberg@tue.nl p.r.beurskens@utwente.nl e.durmisevic@utwente.nl

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ambiguities in application, by providing an accessible level of understanding with the applied adaptations in the model and addition of essential features, such as: re-life option 'reconfiguration', process step 'disassembly', participant '(re) assembler' and coherency with the circular building product levels.

Next to the 'construction domain' and the 'design domain', the framework contains a 'circular building design vision' and 'circular building definition', which should provide guidance in aligning the focus of architects and engineers and provide a robust view on what should be understood as 'a' circular building.

The CBF provides a holistic view on all aspects related to the design and functioning of buildings, which is required in the development a circular building and forms the basis for the development of the MDEM.

TITLE
A morphological design and evaluation model for the development of circular facades

AUTHORS
 ir. M.J.M. Bakx
 ir. M.J. Ritzen
 prof. dr. ir. J.J.N. Lichtenberg
 ir. P.R. Beurskens
 dr. ir. E. Durmisevic

ORGANIZATION
 Eindhoven University of Technology
 Eindhoven, the Netherlands
 University of Twente
 Enschede, the Netherlands

MAIL ADDRESS
 rene357@live.nl
 m.j.ritzen@tue.nl
 j.j.n.lichtenberg@tue.nl
 p.r.beurskens@utwente.nl
 e.durmisevic@utwente.nl

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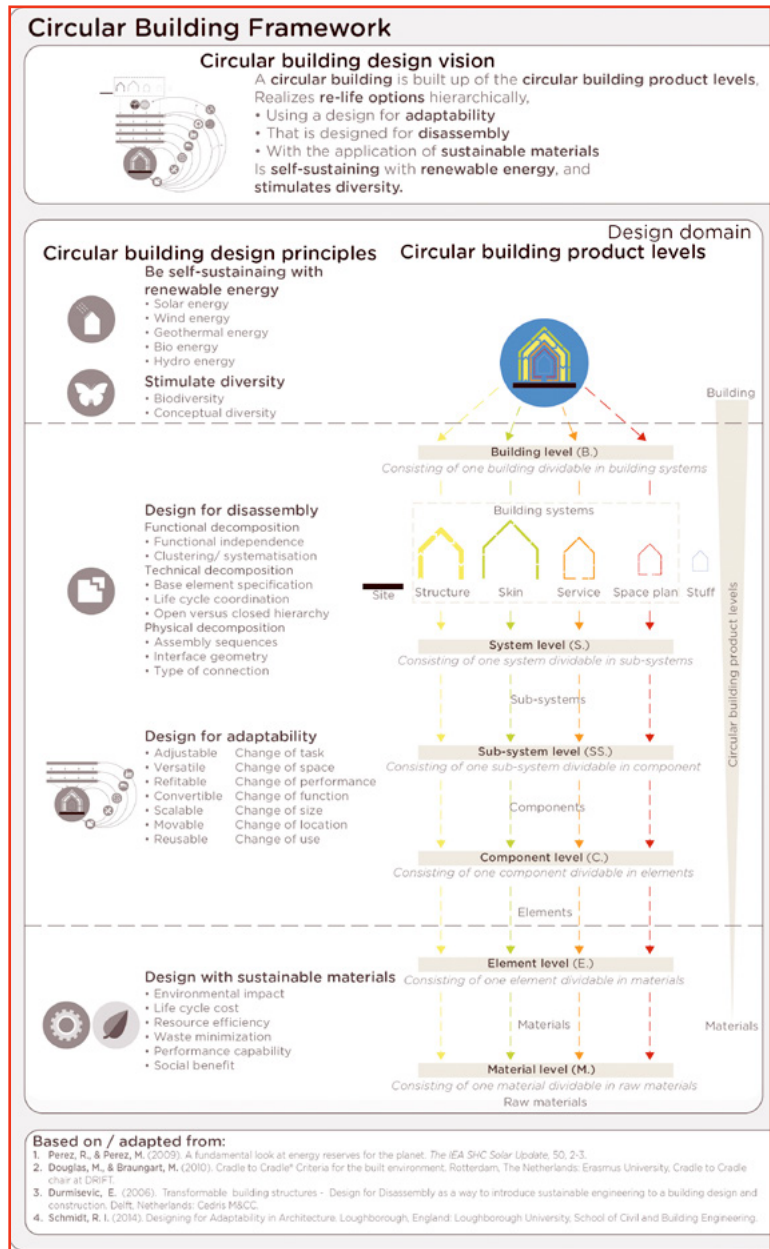


Figure 1: Circular building framework – part 1 of 2 (Beurskens & Bakx, 2015)

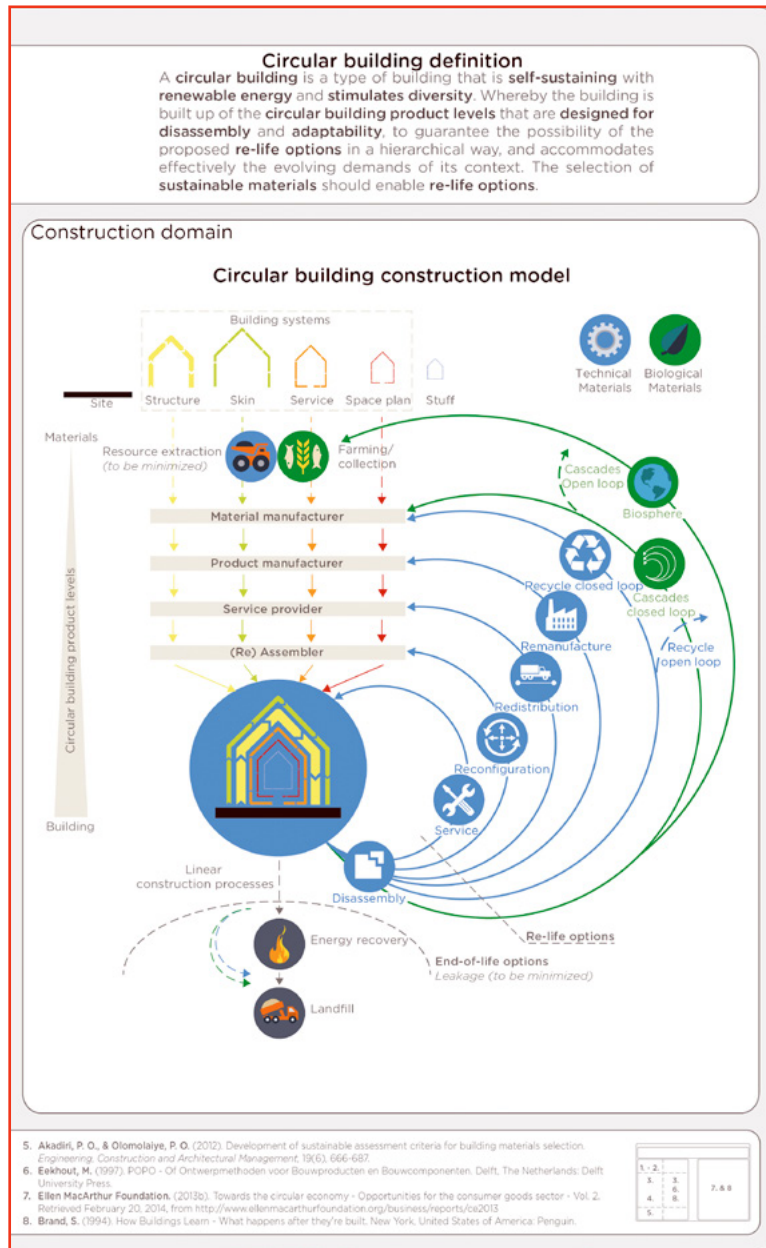


Figure 1: Circular building framework – part 2 of 2 (Beurskens & Bakx, 2015)

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2 Dynamic building structures

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Nowadays, the conception of a building is still dominantly perceived as a solid object. They are conceived, designed, constructed and used as complete entities. However, in the longer time frame, buildings are constantly changing in response to changing user demands and changing environmental conditions (Crowther, 2005). As a result, the building should be seen as a dynamic structure of different buildings over time that may or may not share certain physical parts (Crowther, 2005). This can be reached by applying the systems thinking approach forming a conceptual approach to design dynamic structures based on the division of their parts and relations between those parts. To come up with such an approach the following essential parts from the 'design domain' will be further elaborated, namely: design for disassembly, design for adaptability, and circular building product levels specified for the facade.

2.1 Design for disassembly

Disassembly of existing buildings would be much easier if disassembly had been considered during the design stage (Tingley, 2012), resulting in building components which would get a chance to have multiple lives, and would possibly extend the life cycle of building components (Durmisevic & Brouwer, 2002). In general, disassembly needs to be non-destructive to reuse the building products without destroying the embodied values, such as embodied energy and labour of building components and elements. The application of the principle 'design for disassembly' enhances the applicability of the different re-life options from the circular economy model, and is defined as follows: "The concept of designing buildings in such a way to facilitate future dismantling, thereby reducing the generation of waste by guaranteeing the possibility, of all circular building product levels to undergo re-life options (service, reconfiguration, redistribution, remanufacture, recycling, cascaded use, and biosphere) in a hierarchical way, achieved by the implementation of disassembly determining factors in building design."

The principle 'design for disassembly' focuses on the decomposition of building products by designing them independent and exchangeable, which will be realized by designing building product based on the seventeen disassembly determining factors, according to Durmisevic (2006).

2.2 Design for adaptability

Buildings should be designed according to the principle 'design for adaptability' preventing them from becoming obsolete and turning into waste. As Croxton (2003)

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
A morphological design and evaluation model for the development of circular facades	ir. M.J.M. Bakx ir. M.J. Ritzen prof. dr. ir. J.J.N. Lichtenberg ir. P.R. Beurskens dr. ir. E. Durmisevic	Eindhoven University of Technology Eindhoven, the Netherlands University of Twente Enschede, the Netherlands	rene357@live.nl m.j.ritzen@tue.nl j.j.n.lichtenberg@tue.nl p.r.beurskens@utwente.nl e.durmisevic@utwente.nl

258 points out, “if a building does not support change and reuse, you have only an illusion of sustainability.” The capacity of buildings to respond to ‘change’ is highly determined by design decisions that are made in an early design stage (Schmidt, 2014). The principle ‘design for adaptability’ is defined as: “the concept of designing buildings with the spatial and technical capacity to accommodate effectively the evolving demands of its context, in which its building products are designed to maximize reusability in initial- and other buildings, to minimize value destruction and thus maximize value through life.”

This principle is based on a set of strategies, namely: adjustable, versatile, refitable, convertible, scalable and movable (Schmidt, 2014). According to the circular economy concept building products should not only allow the initial building to be adapted as the strategies defined by Schmidt intend, but also be applicable in other buildings. Therefore, the strategy ‘reusable’ is added, which refers to the ability of building products to change their use, maximizing their life cycle and minimizing value destruction.

The application of these strategies during the design stage can be considered as a comprehensive method of analyzing the different types of changes a building may be forced to endure throughout its life. This analysis allows the designer to make provisions in the building design that enables the building products to react to changing demands and user requirements without the loss of embodied values, which in turn removes the current end-of-life options.

2.3 Circular building product levels

To make the ‘systems thinking approach’ applicable in buildings a systematic description of building configuration through number of product levels that follow the hierarchy of material composition has been made (following the work of Eekhout 1997 and Durmisevic 2006) in order to define the boundaries for independent circular building product levels as: building-, system-, subsystem-, component-, element-, and material level. The circular building product levels will guide designers through the design of dynamic building structures and help them understand the building decomposition hierarchy from Building to material levels.

The circular building product levels are specified for the facade, as shown in Figure 2. The circular building product levels starts with the ‘building’, above building level, which represents the ‘building’ as an assembly of all building systems. These building systems are based on the sharing layers of change from Brand (1994), as represented under building level, in which four main building systems are identified to design

circular buildings. The building system skin is divided in three different subsystems. Within the selected research field, five types of components were identified on sub-system level, and four element functions on component level. Only one specific element function should be assigned to each element and each element should be part of one of the defined components. This should guarantee the independency of its building products to prevent them from premature replacement.

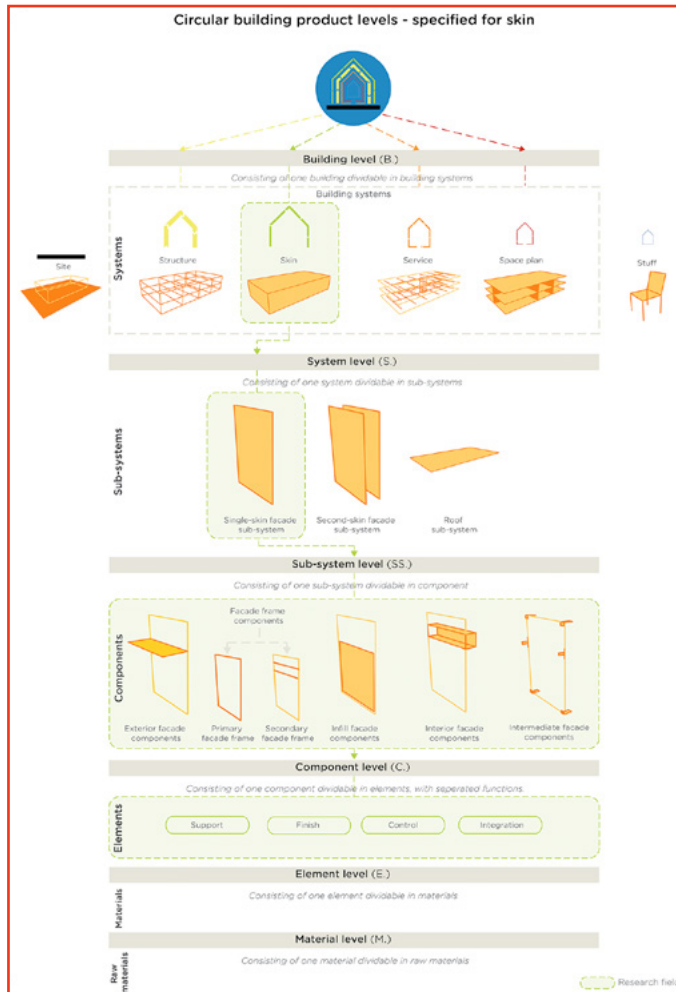


Figure 2: Circular building product levels – specified for skin (Beurskens & Bakx, 2015)

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A morphological design and evaluation model for the development of circular facades	ir. M.J.M. Bakx ir. M.J. Ritzen prof. dr. ir. J.J.N. Lichtenberg ir. P.R. Beurskens dr. ir. E. Durmisevic	Eindhoven University of Technology Eindhoven, the Netherlands University of Twente Enschede, the Netherlands	rene357@live.nl m.j.ritzen@tue.nl j.j.n.lichtenberg@tue.nl p.r.beurskens@utwente.nl e.durmisevic@utwente.nl

3 Morphological Design and Evaluation Model (MDEM)

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There is a need to develop a model based on the CBF that enables an easy application and evaluation of its constituting parts in an integral manner in design practices. In order to come up with a first draft of such a model, an attempt was made, which resulted in the MDEM (Figure 3).

The MDEM is focused on the building system skin, particularly for the design and evaluation of the facade frame components of a single-skin facade system. The developed model integrates the essential principles, 'design for disassembly' and 'design for adaptability', and makes use of the circular building product levels. The integration of the essential principles 'design for disassembly' and 'design for adaptability' in one model that supports the design and evaluation is new in the field of sustainable building design.

This MDEM is developed in a research project with the use of one case study that was extensively analyzed on the principles 'design for disassembly' and 'design for disassembly' (Beurskens & Bakx, 2015). This analysis led to 23 design requirements, which were subdivided over the circular building product levels (Beurskens & Bakx, 2015, p. 70). The MDEM identifies 28 design parameters, which are all determined and assessed on the defined design requirements and the underlying literature (Durmisevic, 2006; Schmidt, 2014). Each parameter consists of different conceptual design options, in which the presented drawings are principle visualizations providing a better understanding of what is intended. These principal visualizations guarantee a variety of design elaborations, which enable the facade designer to react to project specific context and architectural appearance.

All parameters are clustered in two different types of categories, namely properties and intermediate, providing a clear distinction of subjects within the MDEM. The proposed conceptual design options are ranked from circular to linear (option 'a' to 'f'). All selected conceptual design options together form a conceptual design of the circular facade, which can be evaluated with the proposed ranking.

3.1 Subjects of the MDEM (Categories)

The MDEM allows a top-down approach in the design process, which starts at system level with the selection of the type of facade frame. Here the unitised facade system (prefabricated subsystems) is identified as the most circular option, and stick systems (prefabricated components) as the least circular option. On system level, the design parameters 1-16 focus mainly on the position and geometry of the facade subsystems

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(properties), and the applied connections connecting the facade subsystem to the building structure (intermediate), that should also allow exchangeability and repositioning with respect to required spatial changes. The design parameters 17-26 on sub-system level focus mainly on the adaptability of the facade frame in length and depth (properties) and the applied connections within the facade subsystem (intermediate). On the lowest, component level, the design parameters 27-28 are directed to properties concerning installations and finishing elements.

3.2 Conceptual circular facade design solutions

In the MDEM two types of circular facade design solutions can be identified, namely: an adaptable circular facade design and a modular circular facade design. The adaptable circular facade design solution indicates a circular facade frame design with built-in provisions that allow the design to be easily modified and adjusted to all possible changes within the solution area, concerning its: dimensions, connectivity, load bearing capacity and appearance. The modular circular facade design solution is based on modular coordination and standardization of connections, which allows the facade design to be easily adjusted to a fixed amount of pre-defined solutions. The modular solution may be more material effective considering the adaptable solution requires overdimensioning. However, if the construction industry does not align with modular coordination rules, the adaptable solution outweighs the modular solution. Therefore, the adaptable solution that can serve new and existing buildings is identified as preferred solution at this moment, in the transition towards a circular construction industry.

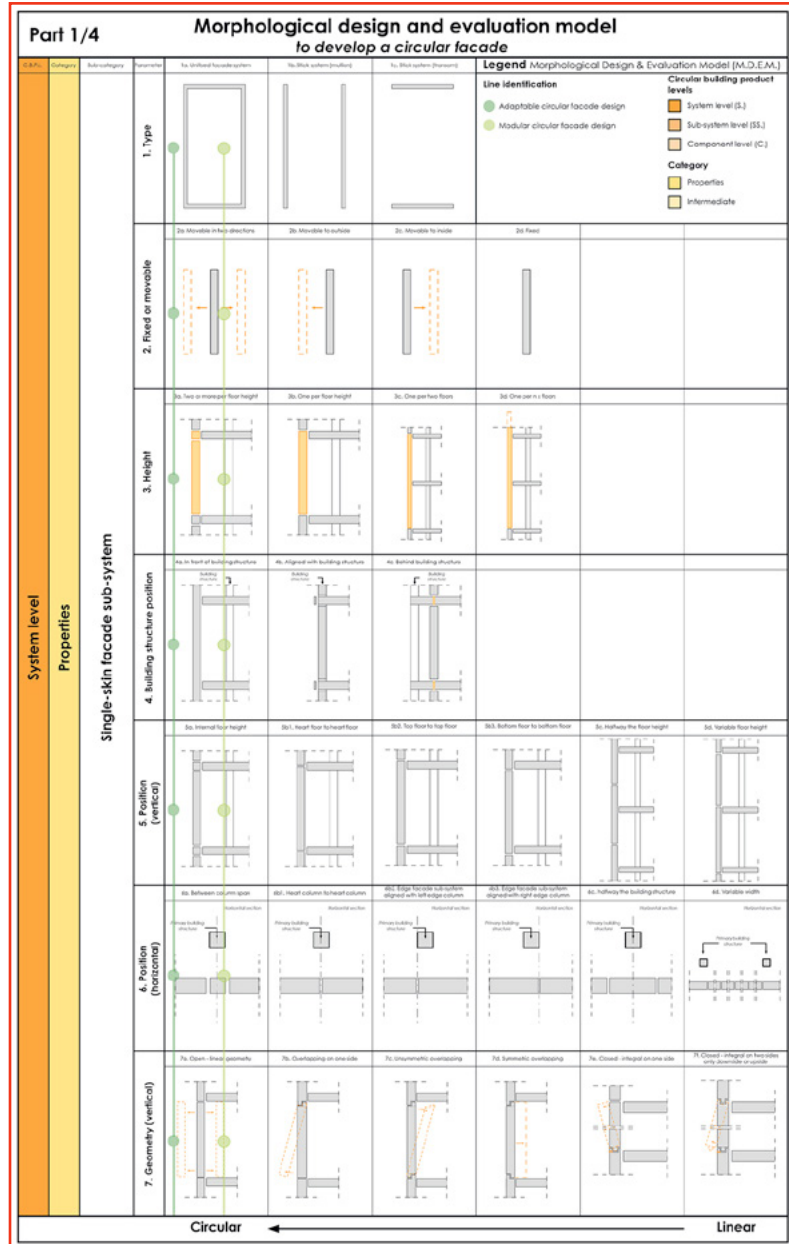


Figure 3: Morphological design and evaluation model – part 1 of 4 (Beurskens & Bakx, 2015)

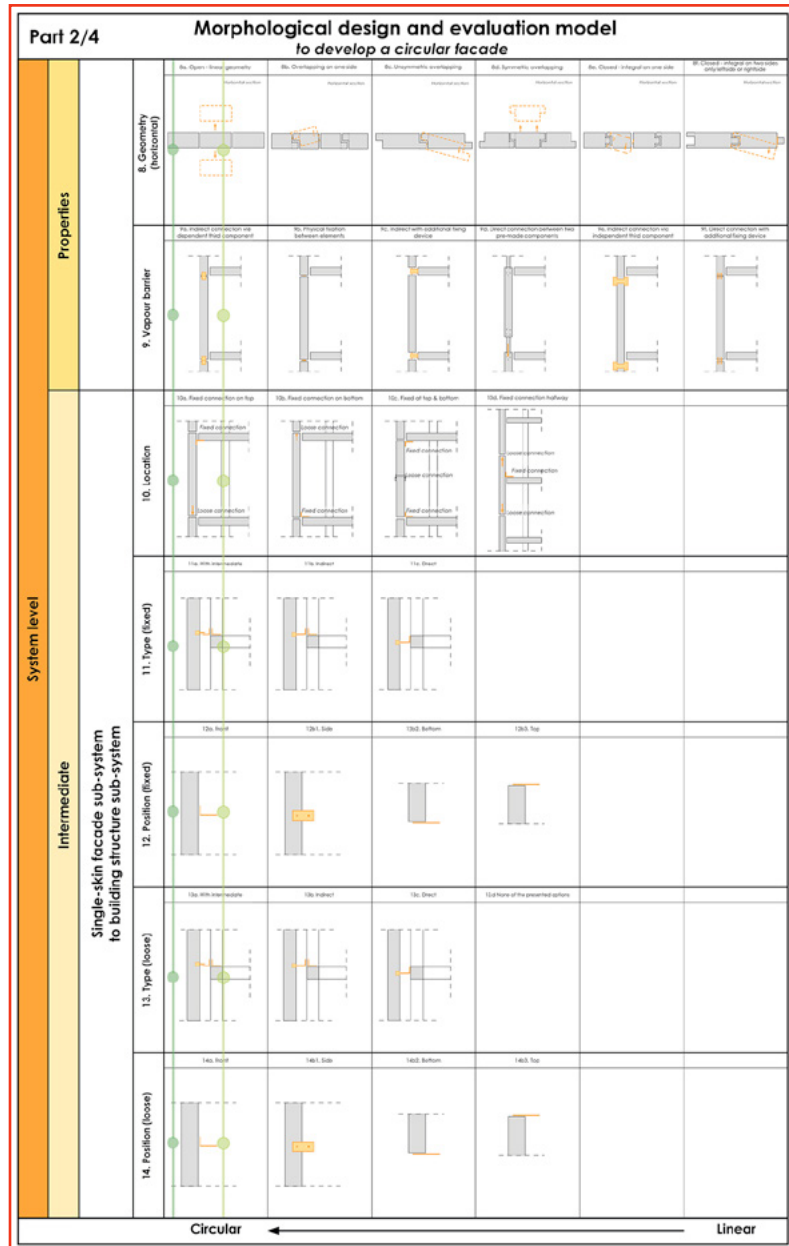


Figure 3: Morphological design and evaluation model – part 2 of 4 (Beurskens & Bakx, 2015)

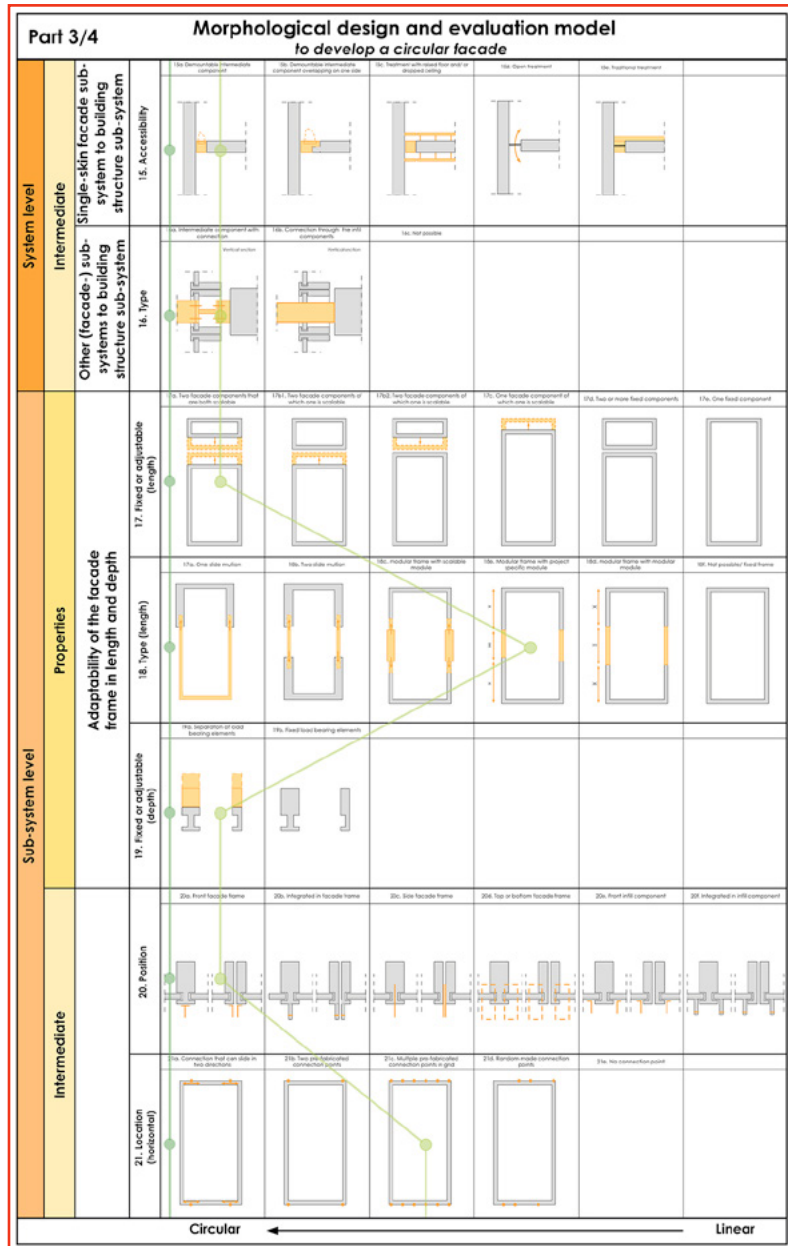


Figure 3: Morphological design and evaluation model – part 3 of 4 (Beurskens & Bakx, 2015)

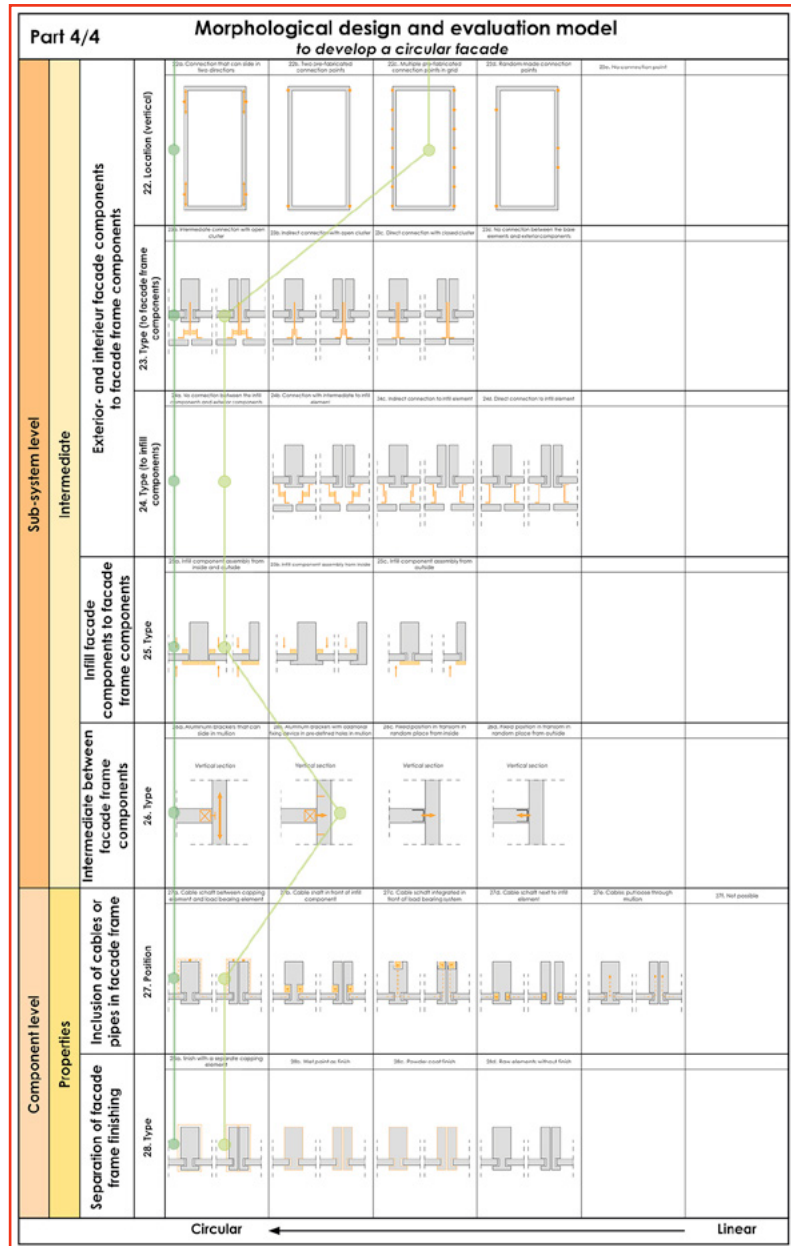


Figure 3: Morphological design and evaluation model – part 4 of 4 (Beurskens & Bakx, 2015)

4 Discussion

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The MDEM is in an early stage of development, in which the presented model is the first draft to guide the designer in the design and evaluation of a circular facade. Currently, the proposed evaluation (from circular to linear) is determined based on one comprehensive case study analysis, resulting design requirements and the underlying literature of the principles 'design for disassembly' and 'design for adaptability' (Beurskens & Bakx, 2015; Durmisevic, 2006 and Schmidt, 2014). In order to bring the model to the next level, it is recommended to apply the model in multiple case studies and reflect on the results to improve the model. The next step could be reached by answering the following questions: Are there dependencies between different parameters and can a minimum requirement be identified in order to call the final design a circular facade design?

Furthermore, in the MDEM an adaptable- and a modular conceptual facade solution were defined, where the adaptable solution is identified as the preferred conceptual design solution, based on rationalization of the conceptual design solutions. To evidence the preferred solution, it is recommended to compare both conceptual design solutions on their environmental impact, confronting multiple case studies. In order to execute a thorough comparison both conceptual design solutions should be elaborated in detail.

5 Conclusions

Current building tradition is characterized as unsustainable due to its linear model of material use. Different strategies to create less environmental impact are investigated where the application of the 'circular economy' concept would probably lead to a less material intensive industry, but however lacks guidance. This research provides a first design guide and asserts that a holistic view on both 'construction domain' and 'design domain' is required to enable the transition towards a construction industry based on a circular model of material use. Since the composition of building products is primordial in allowing them to enter the re-life options at high quality and reclaim embodied values, the following principles are identified as essential: design for disassembly and design for adaptability. The MDEM provides a systematical design approach that guides the designer in the design and evaluation of circular facades, in which the integration of the essential design principles is new in scientific literature of sustainable building.

TITLE	AUTHORS	ORGANIZATION	MAIL ADDRESS
A morphological design and evaluation model for the development of circular facades	ir. M.J.M. Bakx ir. M.J. Ritzen prof. dr. ir. J.J.N. Lichtenberg ir. P.R. Beurskens dr. ir. E. Durmisevic	Eindhoven University of Technology Eindhoven, the Netherlands University of Twente Enschede, the Netherlands	rene357@live.nl m.j.ritzen@tue.nl j.j.n.lichtenberg@tue.nl p.r.beurskens@utwente.nl e.durmisevic@utwente.nl

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FORMULATING A CAPABILITY APPROACH BASED MODEL TO SUSTAIN RURAL SUB-SAHARAN AFRICAN INHABITANTS' SELF- RELIANCE TOWARDS THEIR BUILT ENVIRONMENT

Changing climate conditions and depleting resources are becoming more important on the global agenda. Here the paradigm is shifting to understand which means (resources) are necessary to generate future well-being (Atkinson, 2008). Most Western industries have tried to evolve to meet new requirements. Unfortunately the formal built environment remains the most polluting global industry (WRI, 2015) and due to its conservative character seems difficult to change. Taken attempts often address consequence and not the cause. As a result most technological improvements focus on improving characteristics of material, construction and processes. Continuing this line of thought the developed world perceives that technology has the ability to solve all contemporary environmental problems.

This article argues that in the informal rural African built environment examples of other attitudes towards the same goals can be found. Goals that provide many sustainable solutions that have a circular process and are based on local renewable materials. Arguments are given for perceiving rural communities as a multitude of communities of practices (Wenger, 2012), with a collective (sustainable) intelligence (Leimeister, 2010) towards their built environment. More importantly, this not only provides with a circular and sustainable model, but also with a self-reliant and resilient model for the built environment. This article argues that in order to articulate sustainable 'local' solutions, the inhabitants' self-reliance is of vital importance (Nel & Binns, 2000). Therefore, this article states a need for a model to evaluate what affords the inhabitants' self-reliance and how this model could be used as support for the 'expert' to evaluate the inhabitants' capabilities towards

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their built environment. The model intends global application for both urban and rural informal architecture. This article uses the rural locality as a case to develop the model, as it is relatively easier to study complex environmental, social and economic relations there.

Keywords: self-reliance, rural, community of practice, collective intelligence, situated knowledge, affordances, capability approach.

1 Introduction

With a global population reaching 9.6 billion by 2050 (UN) there is a rising demand for affordable housing. Paul Oliver does not think any government or corporation will be able to build the housing required (Cromley, 2008: 301). It will be up to local communities and inhabitants to develop their own dwellings. Existing informal rural (vernacular) architecture offer a flexible model based on locally available (renewable) materials and building methods. The available global vernacular models often evolved over centuries, passed down to every new generation. Due to the nature and character of the vernacular archetype extensive maintenance is often essential (Smits, 2015). However inconvenient, the continuous process of maintenance allows the community to constantly practice and enhance their built environment (Smits, 2014) and makes them highly resilient towards change (Nel & Binns, 2000:406). Moreover, due to the choice of materials and construction properties the vernacular archetype has the ability to completely dissolve back into nature when its lifespan ceased. The circular sustainable model is still widely used among many rural African communities, which are simply striving to survive (Nel & Binns, 2000:390). Over the last decades rural communities have been trying to improve the living quality of the vernacular model, but the change introduced industrialized materials and 'foreign' construction methodologies. In practice this means although durability and maintenance have improved, the process created significant external dependency (material, construction and labour). The modernization is unsustainable, non-circular and affecting both identity and culture (Rapoport 2008). And, equally important, it diminishes the community's self-reliance towards their built environment.



Figure 1: Rural vernacular, Mt. Elgon, Kenya, 2015 (made by author)

Whatever the reasons, communities do struggle to improve the quality of the existing model using only local, non-industrialised materials and familiar construction methods without external help. In an effort to augment the existing model they use materials and techniques that lay outside the collective intelligence (CI) of the inhabitants. If these communities are to continue the self-reliant model, they need a way to upgrade the model (extend durability, lower maintenance) without damaging its qualities. This article does not elaborate on the various development models: sustainable, top-down or bottom-up. Development is perceived as a general societal aim on the realization of what Robert Chambers calls 'good change' (1995:174-175). Sustainable development has been chosen as a general model for a balanced growth. Sharachchandra (1991) proposes a model with a strong emphasis on the ecological conditions necessary to support human well-being now and in the future. This model will help the 'expert' to grasp what the inhabitants' capabilities in relation to their self-reliant built environment are. Hopefully, sustaining the inhabitants' self-reliance towards their built environment.

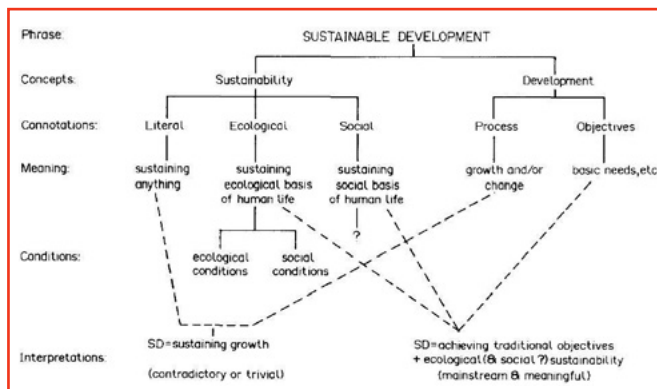


Figure 2: The semantics of sustainable development (Lélé, 1991)

Although total rural independence is an admirable goal, there will always be a relation to a form or degree of external support (material, construction method, labour, etc.). However, it could be of vital importance to improve the current (vernacular) model and that should be the task for architects and engineers (Oliver, 2006). With their expert knowledge on construction, materials and their ability to develop new ways, they could come up with techniques and methods, which are within the abilities and skills of inhabitants. This without reaching for easy unsustainable solutions (e.g. iron sheet roofs). Achieving housing self-reliance would enhance the socio-economical situation of the inhabitants. It would also lessen the dependency from the western aid, making this effort a worthy goal. How the expert intervenes in this process is crucial to the self-reliance of the inhabitants (Prinet, 2000). In order to properly improve the inhabitants built environment the external support should evaluate current inhabitants' self-reliance towards their built environment. To help doing so the article firstly reviews what affords the community's self-reliance towards their built environment. Secondly how these affordances can be projected on their capabilities and thirdly, it articulates the model based on the capability approach (CA) to evaluate what affords the inhabitants' self-reliance. This model will help the 'expert' to grasp what affords the inhabitants' capabilities in relation to their self-reliant built environment are. Hopefully, sustaining the inhabitants' self-reliance towards their built environment.

2 Self-reliance

As introduced above the rural vernacular tradition shows great sustainable and circular examples. They shed a completely different light on how environmental issues could be dealt with. Rural communities are able to construct and maintain their built environment with local renewable materials, circular processes and local knowledge (Idoma & Muhammad, 2013). The community is almost fully able to provide necessary materials, technique and labour without external capital or help (outside one's community). For this reason self-reliance in this article is described as: the ability to independently provide a qualitative built environment on one's own powers, knowledge, materials and construction methodologies (UNHCR, 2006).

Nonetheless, this self-reliant model is based on local, renewable but not durable materials, which decrease housing quality and increase the measure of maintenance (Ashby, 2012). The change in lifestyle and general development demand alterations of the existing model. Without the evaluation of the communities, capabilities the chosen solutions might weaken the communities self-reliance (Li & Ng, 2014). Li & Ng propose a Rural Built Environmental Sustainability Assessment System (RBESAS) to indicate the sustainability (balance) of the development, which is evaluated along

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two axes: Self-reliance Capability and Development Capability (see image below). This model provides with an aim for sustainability that applies to both the developing and developed world.

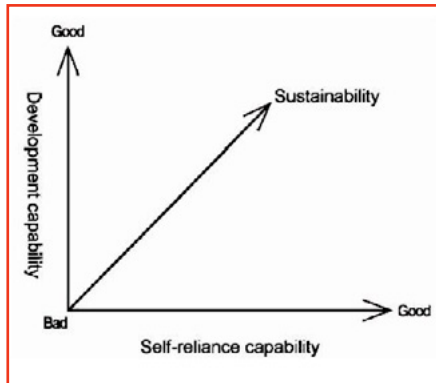


Figure 3: Built environment sustainability of poor rural areas (Li & NG, 1991:5)

2.1 From independence to dependence

However, it proves troublesome to advance the existing informal sustainable model by inhabitants themselves. They often use materials and techniques (bricks, cement, steel, etc.) that lay outside the community's knowledge sphere (capabilities). As a result dependency on non-local materials, labour and knowledge often occurs. A tendency that can be traced back to the development strategies that often deliberately used dependency for external partners to benefit (Grudens-Schuck, et al., 2003). If the communities are to remain self-reliant, a balance between their own and external capabilities ought to be found (Idoma & Muhammad, 2013). Contemporary examples reveal that the 'expert' intervention by the professional is often problematic due to its technological character. Moreover to improve (enhance the quality of building within the inhabitants' reach of material, tools and methods) the inhabitants' built environment their self-reliance should be evaluated. The community's construction knowledge plays the most vital role for sustaining self-reliance towards their built environment. The importance of the local self-reliance (community-based, local resources, etc.) has been recently described in a new development theory called: African renaissance (Matunhu, 2011). Fonchingong & Lotsmart (2003) explain that independence is important however, there will be a necessity of external technical and financial support, as inhabitants themselves proved not to be able to formulate a sufficient way of upgrading their built environment. Thus concluding there is a role for the external support and knowledge.

2.2 Collective intelligence, embedded knowledge and situated learning

In the traditional built environment the community acted as a collective to provide each other with habitation. Inhabitants (on the family scale) individually evaluated their situation within the built environment. The built environment provides with the most long lasting human artifacts as a part of our collective cultural memory (Cole, 2000). Families were able to live self-reliantly but interdependent on other families (community). This group of families constructed and developed the dwelling archetype together. The archetype is a shared cultural perception, which is perceived as an articulation of a community's common goal. In other words it means there is a 'collective intelligence' of the community towards their built environment. Leimeister (2010: 245) defines collective intelligence as a group of individuals who are not required to have the same points of view, but can have different perspectives and approaches. Their shared intelligence refers to their ability to learn, understand, and adapt to an environment. It enables the collective to deal with changing and difficult situations.

The collective intelligence of rural vernacular architecture is often misunderstood due to the lack of formalized knowledge. The absence of this 'explicit' knowledge (Brown et al., 1998, Allee, 2000, Frost, A., 2010) can be explained by the high level of intuitive and experience based knowledge. This 'tacit' knowledge (Polanyi, 1962) is deeply rooted in action, commitment and involvement (Nonaka, 1994). Furthermore because of the community involvement, this 'embedded' knowledge (Collins, 1993) is articulated in all processes and products, concerning their built environment. It is not a model or a framework but a way of learning that occurs in the every day. A form of learning what Cobb (1999) calls situated learning:

The theory of situated learning claims that knowledge is not a thing or set of descriptions or collection of facts and rules. ...Human knowledge should be viewed as a capacity to coordinate and sequence behaviour, to adapt dynamically to changing circumstances.

2.3 Community of practice (CoP)

The model of vernacular construction processes reveals itself as an example of the situated learning (Smith, 2003, Wenger, 2012) which is transferred by every generation of children, based on legitimate peripheral participation (Wenger, 2012). It consist of various elements, such as: water fetching, mud mixing, wall filling and rope making. Every task is performed by a mixed (age) group of participants and varied levels can be clearly distinguished (from novice to expert). This group is what Lave and Wenger call communities of practice (CoP). The participation in a CoP

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according to Wenger (1999) is not only a shared activity but it encompasses a shared interest, which can involve people in any type of activity. These activities do not only concern construction but range to aspects of community (like: washing, bathing and cleaning). There is a major overlap in daily and constructing activities. However they can be reduced to three basic elements as Wenger (2012) proposes:

- What it is about
- How it functions
- What capability it has produced



Figure 4: Various CoP, Mt. Elgon, Kenya, 2011 (made by author)

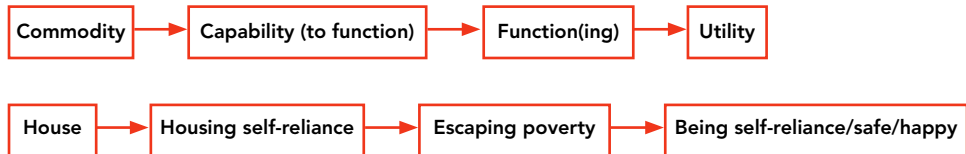
3 Capabilities

Capability generally means the quality of being capable; capacity; ability. Within the context of this article capability is analysed to what extend one is capable or able to effectively formulate their built environment. Developing on one's own abilities will be essential for the self-reliance of sub-Sahara (Willer, 2002). The capability approach (CA) is based on the same definition. Which, for this purpose forms the departure point to understand what is realized (functionings) by inhabitants and what is actually possible (capabilities). Capabilities are described as a person's ability to achieve a given functioning: doing or being (Sen, 1993).

3.1 The Capability Approach

The Capability Approach (CA) introduced by Sen formulates an alternative economic framework to look at poverty, inequality and human development in general (qtd. Clark, 2005). Sen (1993) distinguishes basic capabilities. The basic capability is the ability to satisfy certain elementary functionings up to a certain level. For the

purpose of this investigation of habitation is of vital importance for survival or to escape poverty (Robeyns, 2011.). Sen, describes this phenomenon as follows (qtd. Clark, 2005):



The capability approach is a normative economical framework that provides a theory on how (individual or group) well-being could be assessed. However, there are only few research examples that use the CA for the evaluation of a group's decision making or evaluation process (Robeyns, 2011). Li's & Ng's, investigation (2014) seems one of the few examples that used the CA in the evaluation of the built environment. They formulated a list of indicators based on a set of capabilities. Here a distinction between self-reliance and development capabilities is being made:

- *Self-reliance capability: To meet basic human needs without over reliance in outside resources under existing bio-capacity, and at the same time, does not reduce bio-capacity*
- *Development capability: To increase the bio-capacity, and to meet human psychological needs for better development*

For figure 5: 'Framework of RBESAS indicators' see next page.

RBESAS	Self-reliance capability	1. Land & resources conservation	1.1 Sensitive areas conservation 1.2 Agricultural land conservation 1.3 Soil and water conservation
		2. Waste management	2.1 Construction & demolition waste management 2.2 Operation waste management
		3. Pollution control	3.1 Pollution-free construction & demolition 3.2 Pollution-free agriculture
		4. Food self-reliance	4.1 Local food production 4.2 Diversified farming
		5. Water self-reliance	5.1 Water quality 5.2 Water efficient irrigation 5.3 Water efficient buildings & appliance 5.4 Water reuse
		6. Housing self-reliance	6.1 Regional materials 6.2 Efficient use of materials 6.3 Indoor environmental quality 6.4 Housing affordability
		7. Safety and security	7.1 Settlements location 7.2 Safety and security design
		8. Health & well-being	8.1 Living environmental sanitation 8.2 Community basic services 8.3 Community recreation facilities and open spaces
		9. Energy self-reliance	9.1 Embodied energy of materials 9.2 Energy efficient buildings & appliance 9.3 Local & renewable energy
		10. Economic self-reliance	10.1 Local economy improvement 10.2 Activation & empower
	Development capability	11. Sustainable landscaping	11.1 Biocapacity improvement
		12. Sustainable agriculture	12.1 Circular agriculture 12.2 Biological controls
		13. Culture & context	13.1 Protection of historical & cultural heritage 13.2 Keep local characteristics 13.3 Coordination with natural environment
		14. Inclusiveness & participation	14.1 Barrier-free facilities 14.2 Public engagement
		15. Education & information	15.1 Education space and facilities 15.2 Information facilities

Figure 5:
 Framework of RBESAS indicators (Li & NG, 1991:6)

Li used the indicators to analyse to what level they could successfully evaluate the sustainability of a rural community towards their built environment. However, uncertainty remains whether the indicators cover all aspects of the capabilities. Moreover, it does not explain what the various indicators afford in relation to a self-reliant and sustainable build environment. This article will focus on deepening *Regional materials* (Fig. 5) by looking at one specific scenario: housing component (door) made out of two different regional materials (Mahogany hardwood & steel).

For example: To understand how *Regional materials* (Fig. 5, 6.1) enable Housing self-reliance (Fig. 5, 6) we first need to zoom in on the housing component. Second, on what the possible available regional materials are. Thirdly, evaluate how they result in possible positive and negative affordance in relation to the user capabilities and self-reliance.

3.2 Affordances of self-reliance

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To be able to describe the factors that influence the self-reliance capability indicators we can't solely look at how they interrelate and function. For example:

- factor A (door) + factor B (regional material) doesn't have to result in a sustainable regional material (6.1)

The regional material could for instance be a local hardwood. Because it grows over decades, it could very well be unsustainable to use as a construction material. Moreover, this hardwood might be regional but not owned by the inhabitant. For this reason the inhabitant would need financial capacity, which would (when used) influence other capacities (eating, drinking, learning). To look beyond the scope of functionings, Gibson (1979) proposes an affordances model (qtd. Maier & Fadel, 2002). Here the influence between the various factors is seen within their environment. An artifact is no longer perceived to result in a certain specific function; it has the ability to afford many things (outside the scope of base function). As not all affordances have positive effects, the theory makes a distinction between positive and negative affordances.

Maier & Fadel (2009) use the affordances to formulate a framework in the evaluation of engineering and design processes. Uzzell & Clark (2002) give a good example on the evaluation of affordances within the built environment. The artifact affords desired and undesired purpose(s). The artifact in the proposed new framework can either be a commodity, resource or skill (Maier & Fadel, 2009c). It can have either positive or negative affordances to a multitude of capabilities and by being so not only evaluating cause and effect, but a multitude of effects. Affordances can be divided into two broad categories (Maier & Fadel, 2009a, 2009b): artifact-user affordances (AUA) and artifact-artifact affordances (AAA).

The proposed indicator (Li & Ng, 2014); *Regional material* (Fig 5, 6.1) can be interpreted as one half of the total group of materials (regional/non-regional materials). In the provided example two materials, mahogany hardwood and steel (regional/non-regional materials), are evaluated and applied in the housing part: door. The main structure of generic affordance template (Fig. 6) of Maier & Fadel (2009:230) (white boxes) is used.

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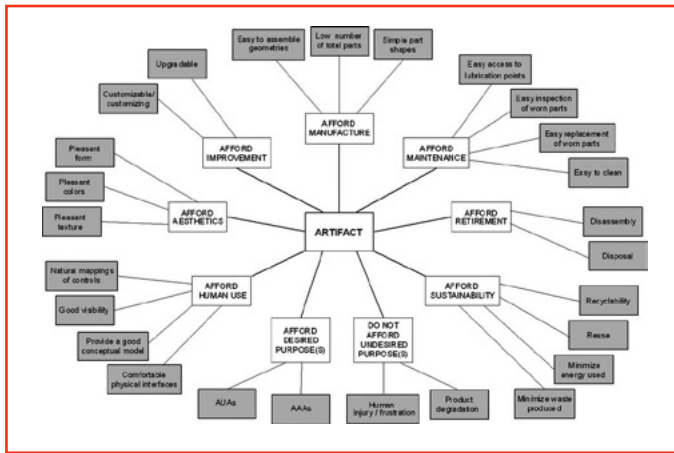
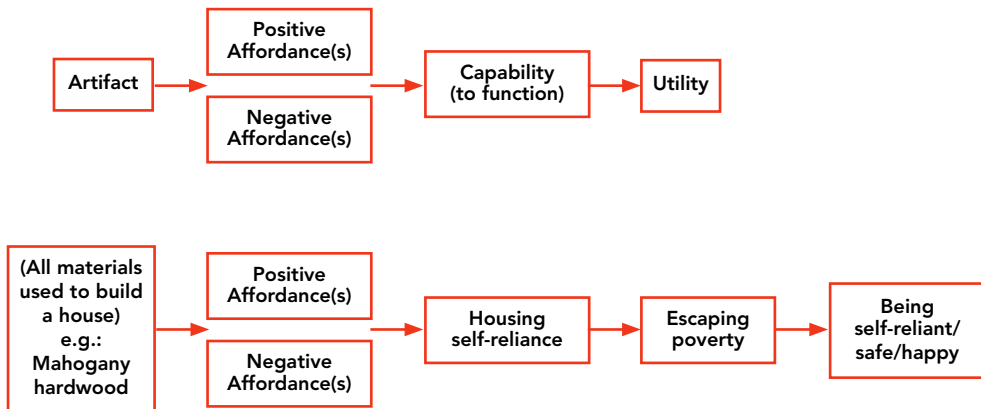


Figure 6: Generic affordance structure template (Maier & Fadel, 2009: 230)

4 A model to evaluate affordances that enable community capabilities towards their self-reliant built environment

This article argues that although Gibson’s CA gives a model to understand individual well-being, it does not evaluate the interrelations between resources (commodities and skills) and capabilities. Moreover it narrows the commodity(-ies) as the functional part of a capability, as an effect the characteristics (positive and negative affordances) are not sufficiently evaluated. To evaluate and incorporate these aspects this article outlines the following addition to the model:



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To solve the complexity of relations Mocko et al. (2007) proposes several matrix-based methods: Design Structure Matrices (DSMs) and House of Quality (HoQ). These have been developed to evaluate the information and relationships in engineering systems, but could be of vital importance to explain complex designer user relationships. However, their analysis also focuses mainly on requirements and functions. Maier & Fadel (2009) propose an Affordance Structure Matrix (ASM), which is similar to DSM and HoQ, but is specific to affordances. Here the different affordances are weighed against the different components of a certain artifact.

Looking at the indicators (figure 5) of Li & Ng (2014) to evaluate self-reliant housing (regional materials, efficient use of materials, indoor environmental quality, housing affordability), it could be argued whether they sufficiently cover all capabilities (in relation to self-reliant housing). In an effort to formulate a clear and complete scope of all capabilities relating to self-reliant housing, the following capabilities are proposed:

- Maintainability
- Affordability
- Liveability
- Improvability
- Aesthetics
- Sustainability
- Suitability
- Flexibility
- Usability
- Comfortability

This list of capabilities is merely an attempt to cover the different themes related to self-reliant housing. Any such endeavour without the direct involvement and evaluation of a given situation (inhabitant/community) seems futile. However, it is necessary in order to properly analyse all dimensions of such circumstances as input to the model

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described in this article. The described model in this article is not meant as a critique on the CA, but more an applied articulation to the field of the built environment. It tries to help inhabitants to sustain a self-reliant attitude towards their built environment.

In the figure below the various affordances are described and weighed in relation to regional materials (see Fig. 5) on the example of a door (one of the house components).

House components			door	hardwood	steel	withdow	wall	roof	floor	foundations	ceiling	Etc.	
AUA+ (positive)	Availability	1	Material is locally available (no transport)	+	+								
		2	Material is directly available (owned or free)	+	+								
		3	Provides all door components (frame&board)	+	+								
	Desired purposes(suitability)	4	Provides thermal comfort	+	+								
		5	Provides banier (burglary)	+	+								
		6	Provides barrier (from outside weather)	+	+								
		7	Provides barrier (visual)	+	+								
	Maintenance	8	Maintenance (feasible or little)	+	+								
		9	Treatment feasibility	+	+								
	Manufacture	10	Self-construction	+	+								
		11	Pleasant texture	+	+								
	Aesthetics	12	Pleasant colour	+	+								
		13	Pleasant pattern	+	+								
	Improvement	14	Allows adjustments	+	+								
		15	Disassembly	+	+								
	Retirement	16	Disposal	+	+								
		17	Reusability (as the same object)	+	+								
	Sustainability	18	Reusability (as something else)	+	+								
		19	Recyclability	+	+								
		20	Minimize waste	+	+								
		21	Minimize energy use	+	+								
AUA-(negative)	Availability	22	Material is not locally available (transport needed)	-	-								
		23	Material is not directly available(paid)	-	-								
	Undesired purpose (unsuitability)	24	Injure workers	-	-								
		25	Injure inhabitants	-	-								
		26	Radiate (cold/heat)	-	-								
	Maintenance	27	Maintenance(demanding or frequent)	-	-								
		28	Complex treatment	-	-								
	Manufacture	29	External tools necessity	-	-								
		30	External labour necessity	-	-								
	Sustainability	31	Deforestation	-	-								
		32	Renewability(material)	+	+								
AAA+ (positive)	Sustainability	33	Long lifespan	+	+								
		34	Biodegradability	+	+								
	35	Durability	+	+									
	36	Dimension stability	+	+									
AAA- (negative)	Undesired purpose	37	Fire hazard	-	-								
		38	Expansion under heat	-	-								
	Sustainability	39	No renewability	-	-								
		40	Vulnerability to insects	-	-								
	Maintenance	41	Vulnerability to climate conditions	-	-								
Total Positive Affordances			22	10									
Total Negative affordances			6	10									
Total Helpful			31	15									
Total Harmful			9	25									
Grand total			40	40									
Percent Positive Affordances			0%	40%									
Percent negative Affordances			40%	67%									
Percentage difference			-40%	-27%									
Percent helpful			78%	38%									
Percent harmful			23%	63%									
Percentage difference			55%	-25%									

Figure 7

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In the example above the two materials (mahogany hardwood and steel) are evaluated as a part of a door example in the following elements:

- How many positive affordances each option has
- How many negative affordances each option has
- Total number of helpful relationships (positive affordance an option has plus the number of negative affordances it does not have)
- Total number of harmful relationships (positive affordances an option does not have plus the number of negative affordances it does have)
- Percentage helpful
- Percentage harmful
- Percentage difference (percentage helpful minus percentage harmful)

As shown in Table I, using the list of capabilities as departure point various affordances (positive and negative) for both artifact-user affordances and artifact-artefact affordances, can be formulated. Moreover can the number of helpful and harmful relationships be evaluated and an overall helpful or harmful percentage be calculated. In this case it results in a largely positive evaluation of the mahogany hardwood door and a rather negative evaluation of the steel. Both results weighed on the affordances based on the possible capabilities of the inhabitant (assumed) aiming to advise the most self-reliant and sustainable option for the inhabitant.

Note: in this example equal weighting is assumed for each affordance. A comparable ASM could be described not only for one part (door) but for a group of parts and even a whole house (self-reliant housing). In this matrix the various affordances necessary for self-reliant housing can be evaluated in relation to the house component, per material.

5 Conclusions

This article has outlined different approaches to understand how user capabilities can be related to the build environment based on affordances. As a result it identified a model (ASM) where the affordances can be weighed and evaluated according to the housing component per material. The list of affordances articulated and prioritised

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in this article were formulated without user involvement. This list gives a theoretical list of affordances to be evaluated together with the user for completeness. This will prevent blind spots from occurring by either designer or user side. The process of formulating and prioritizing affordances will be discussed in the next article.

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SUSTAINABLE BUILT ENVIRONMENT: TRANSITION ZERO

This publication is based on papers which were submitted for the Utrecht SBE16 conference: Transition Zero, from Demonstrations to large-scale Net-Zero Refurbishment in Utrecht (the Netherlands) on 7-8 April 2016. The SBE conference series – endorsed by CIB, iiSBE, UNEP-SBCI and FIDIC – is considered to be the pre-eminent international conference on sustainable building and construction. The conference was hosted by HU University of Applied Sciences Utrecht and several Dutch partners, under the auspices of the European Union. The convention has brought together an audience of technology transition professionals in urban sustainability from all around Europe and beyond.

More than 50 papers were submitted for the conference, which deepened the collaboration between professionals – academic as well as practitioner-driven – from both the private and public sectors who share the same passion for sustainable building and construction. The conference also included a special session for students, the Young Professionals Event, in which student teams were challenged to compete for the Transition Zero Award.

This publication aimed to promote a wide range of research and practice-based projects covering the four conference topics:

- Upscaling: from prototypes and concepts to market introduction, financial & business models and strategy to mass market
- Governance: legislation & policies, European chances, stakeholder involvement and impact of local/national authorities
- Small urban area: energy optimizing systems, 0-impact areas related to energy, water & materials, participation of inhabitants and quality of life
- Circular processes: models & materials, construction chains, eco-materials and embedded energy

In addition to the presentations on these four conference topics, there were lectures about various European projects with impact on the Transition to Zero Energy, and presentations of several student teams on Zero Energy during the Young Professionals Event.

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