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INNOVATION MEETS MARKET
SBE19 CONFERENCE
5—6 NOVEMBER 2018 – TU/e, EINDHOVEN (NL)

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Comparison Of Weekdays' And Weekend's Indoor Environment In Green Low-income Homes

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ABSTRACT

The goal of this study was to investigate hourly variation of indoor environmental quality (IEQ) in green low-income residential buildings using less sophisticated IEQ equipment. Concentrations were grouped into two categories: (a) weekdays and (b) weekend. Independent t-test was subsequently used to test the differences in these categories. The differences in diurnal cycles of indoor carbon monoxide (CO) and particulate matter (PM) concentrations for weekdays and weekend during the fall season were statistically significant. Similar observation was reported for relative humidity (RH). During the winter period, statistical significance was only observed in temperature.

Keywords: Indoor air quality; thermal comfort; green buildings; indoor environmental quality

1. INTRODUCTION

The effects of exposure to toxic pollutants, although more pronounced in low-income households (Brown et al., 2015), have received less attention. Poor housing conditions could be detrimental to occupants' quality of life (Cho et al., 2011). Globally, low-income houses are more likely to be retrofitted to improve performance compared to other classes of housing (Breysse et al., 2011, Breysse et al., 2015, Doll et al., 2016) because of their characteristically poor conditions. Although studies showed significant improvement in energy performance following retrofitting, evidence to support similar claim for IEQ is sparse. One of the main reasons for this inadequate attention is the limited understanding of the indoor environment. Moreover, IAQ problems can hinder energy retrofit strategies e.g. window opening can lead to increased energy consumption (Gupta and Kapsali, 2016). Much is revealed about the indoor environment, including the subtle seasonal and hourly variations, through continuous long-term evaluation compared to snapshot measurements. Another failure of previous IEQ studies is the neglect of the possible different operation conditions of homes, particularly during weekdays and weekends. This study serves as a preliminary investigation attempting to fill this gap and to challenge conventional design assumptions for retrofitting. This study investigates changes in IEQ that may be as a result of seasons and weekly operations. The study will be of utility to designers, policymakers and facility managers in the design, maintenance and operation of green low-income housing on how to leverage on different operation conditions to improve IEQ.

2. METHODS

Indoor concentrations were measured in the living rooms of single-family green residential apartments during heating (winter, December 2016-February 2017) and non-heating (fall, September-November 2016) seasons. These homes are located in Manitoba. The Manitoban

Province has a temperate climate (i.e. subarctic climate zone), with monthly precipitation averages of 19 mm in January and 48 mm in September. The average monthly maximum and minimum temperatures in September and January are 19 ºC and 5 ºC and -13 ºC and -24 ºC, respectively (Climate-Data.org). Often finding inexpensive, easy-to-use, and accurate sensors and equipment is usually a challenge in IEQ evaluation (Heinzerling et al., 2013). With the common commercial sensors, their cost and cost of calibration have been reported as a major hindering factor to the use of objective methods in IEQ studies (Mui et al 2016). In this study, simple foobot air quality equipment was used to monitor CO, CO_2, PM, TVOC, Temperature and RH. Compared to existing sensors, these equipment are less-sophisticated and also allow a real-time monitoring of indoor environment remotely. The equipment logged every 5 minutes. Only two apartments were investigated as part of this preliminary study and living room where occupants spent much of their time and thus carried most of their activities was deemed representative of the apartment. The average number of people per home was 6. Data were analysed using parametric independent t-test to test the statistical difference between the two categories.

3. RESULTS AND DISCUSSIONS

This section presents the results and discussion of the study. Table 1 summarizes the results. During the fall period, significant difference in CO was reported between weekdays and weekend ($p = .00$, $t = -7.74$). The diurnal cycle of indoor CO concentration for the weekend had a characteristic steady trend with a sudden rise in the night (after 7 p.m.), while the diurnal cycle for the weekdays had two characteristic mild peaks, during the morning (8:00–9:00 a.m.) and the evening (4:00–5:00 p.m.). The mild rise in both the morning and evening during the weekday may correspond to a higher traffic flow (perhaps from the nearby highway) during those times of the day as people commute to and from work respectively. Further, the level of concentration on weekend was always higher than weekdays' concentrations (WD mean = 50.79; WE mean = 87.25). Again, this result was expected since it has been postulated that outdoor sources of CO might be the reasonable influence of the indoor levels (Chaloulakou and Mavroidis, 2002). The apartments have windows opened which would maximize the infiltration of outdoor CO in the apartments. However, no information on air exchange rate which would have been helpful to understand exchanges between indoor and outdoor environment. Notwithstanding, this point is emphasized in the insignificant difference for the winter period where infiltration of outdoor concentration is negated by the closing of windows all the time for thermal comfort. For PM, significant differences between the categories only existed in the fall period ($p = .01$; $t = 2.75$). As showed in Table 1, hourly mean concentration during weekdays was higher than weekend (approximately 15 $\mu g/m^3$). During the fall period, the diurnal cycle revealed interesting contrast in the evening after 4 p.m. Whilst weekdays level of concentration steadily declined, the concentration during the weekend skyrocketed. The concentration level on weekdays was consistently higher than the weekend for most part of the hours of the days.

Statistically significant difference between weekdays and weekend was observed in RH during the fall period. The differences between weekdays and weekend appeared to vary widely during the early hours of the day (3:00-8:00 a.m.) and the gap closes as the day progresses. Occupants' activity during the latter part of the day may be the probable explanation to this considerable change in this trend in RH. For instance, heating of water and cooking of meal will certainly give rise to levels in RH as observed by the measurement results of this variable in the evening (Jian et al., 2011). It is also worth noting that although all indoor pollutant mean levels were within the reference national threshold, levels of CO_2 in winter (1593 ppm; 1582 ppm) and in fall (1113 ppm; 1042 ppm) measuring periods exceeded reference exposure levels (1000 ppm or 650 ppm above ambient level) thus compromising IAQ. This highlights the problems of adequate ventilation system to reduce the concentration of CO_2 by the presence of occupants.

TABLE 1: COMPARISON OF INDOOR ENVIRONMENTAL PARAMETERS

		Fall				Winter			
		Mean	SD	t	p	Mean	SD	t	p
CO (ppb)	WD	50.79	8.58	-7.74	.00*	43.11	11.13	-.43	.67
	WE	87.25	21.41			44.39	9.75		
CO_2 (ppm)	WD	1113.11	237.95	1.25	.22	1592.95	429.31	.09	.93
	WE	1041.63	147.06			1582.33	350.07		
PM (μg/m^3)	WD	36.37	9.79	2.75	.01*	8.68	2.11	-1.14	.26
	WE	21.46	24.13			10.00	5.25		
TVOC (ppb)	WD	307.68	65.53	1.25	.22	439.62	118.20	.09	.93
	WE	288.01	40.50			436.89	96.38		
Temperature	WD	22.50	0.51	-1.09	.28	21.96	0.44	2.88	.01*
(^{0}C)	WE	22.68	0.58			21.54	0.57		
RH (%)	WD	40.89	0.38	5.67	.00*	33.84	0.43	.44	.66
	WE	39.99	0.68			33.71	1.34		

WD = Weekdays; WE = Weekend; * = significant at 5% level

4. CONCLUSION

This study investigated the weekly variations in thermal comfort and IAQ over two seasons. Concentration levels peaked in the mornings and evenings during weekdays for most of the pollutants implying the influence of occupants' activities on IEQ. Overall, the indoor levels were all within recommended levels, aside CO_2. TVOC and CO_2 followed a similar pattern implying perhaps insufficient ventilation especially during the winter period. Weekly variation was found to influence thermal comfort and IAQ, this suggests potential design and control problems which could be addressed during design stage and occupant education at occupancy stage respectively. This also challenges the conventional design assumptions that seem to disregard possible occupant indoor conditions during weekdays and weekend.

REFERENCES

BREYSSE, J., DIXON, S. L., JACOBS, D. E., LOPEZ, J. & WEBER, W. 2015. Self-reported health outcomes associated with green-renovated public housing among primarily elderly residents. *J Public Health Manag Pract,* 21**,** 355-67.

BREYSSE, J., JACOBS, D. E., WEBER, W., DIXON, S., KAWECKI, C., ACETI, S. & LOPEZ, J. 2011. Health Outcomes and Green Renovation of Affordable Housing. *Public Health Reports (1974-),* 126**,** 64-75.

BROWN, T., DASSONVILLE, C., DERBEZ, M., RAMALHO, O., KIRCHNER, S., CRUMP, D. & MANDIN, C. 2015. Relationships between socioeconomic and lifestyle factors and indoor air quality in French dwellings. *Environ Res,* 140**,** 385-96.

CHALOULAKOU, A. & MAVROIDIS, I. 2002. Comparison of indoor and outdoor concentrations of CO at a public school. Evaluation of an indoor air quality model. *Atmospheric Environment,* 36**,** 1769-1781.

CHO, S. H., LEE, T. K. & KIM, J. T. 2011. Residents' Satisfaction of Indoor Environmental Quality in Their Old Apartment Homes. *Indoor and Built Environment,* 20**,** 16-25.

DOLL, S. C., DAVISON, E. L. & PAINTING, B. R. 2016. Weatherization impacts and baseline indoor environmental quality in low income single-family homes. *Building and Environment,* 107**,** 181-190.

GUPTA, R. & KAPSALI, M. 2016. Empirical assessment of indoor air quality and overheating in low-carbon social housing dwellings in England, UK. *Advances in Building Energy Research,* 10**,** 46-68.

HEINZERLING, D., SCHIAVON, S., WEBSTER, T. & ARENS, E. 2013. Indoor environmental quality assessment models: A literature review and a proposed weighting and classification scheme. *Building and Environment,* 70**,** 210-222.

JIAN, Y., GUO, Y., LIU, J., BAI, Z. & LI, Q. 2011. Case study of window opening behavior using field measurement results. *Building Simulation,* 4**,** 107-116.

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Retrofitting from the Inside/Insight Perspective:
Adapting to Users' Needs with the Kitchen as a Starting Point

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ABSTRACT

Premature renovation of kitchen furniture and appliances lead to waste and unnecessary climate impact. One important driver to premature kitchen renovations is a lack of understanding of user needs among designers, developers and kitchen producers. This project aims at developing a future circular kitchen based on user insights studies combined with co-creation sessions involving different stakeholders in the supply chain of kitchen production, maintenance, use and recycling. Implication of user insights on liveability of dwellings for the broader sustainable retrofitting agenda is discussed.

Keywords: circular kitchen; user behaviour; liveability

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1. INTRODUCTION

The transition towards circular economy has been emphasised as a means to reach International climate goals (Swedish Government, 2017). These transitions require that changes are made in both the consumption and the production systems (EEA, 2017).

A recent Swedish study showed a mismatch between offer and demand of owner-occupied apartments. As a result, modern apartments are subject to internal renovation by the end-users only after a few years in use (Femenías, et al., 2016). Reasons behind these premature renovations are a lack of quality of materials but also a lack of quality of the design, reflecting a knowledge gap about user needs and user behaviour among designers and producers of apartments. The material flows caused by these premature renovations were estimated to generate 40 % more CO_2 equivalents than a normal maintenance cycle. As expected, and also stated in other studies (Maller et al., 2012), kitchens were among the most renovated parts of the dwellings. Replacements of appliances and cupboards in the kitchen contributed to more than 35 % of the climate impact of an average apartment. In addition, extrapolated over 50 years, these internal renovations correspond to one fifth of the total climate impact of the apartment when delivered. The impact of material flows in the use phase is expected to increase as buildings become more energy efficient in use and energy sources become cleaner, unless more circular designs are developed.

1.1. Purpose

This paper explores an inside or insight perspective to more circular solutions based on users' needs and how this knowledge can add value and improve the agenda for retrofitting of housing on a larger scale. So far, sustainable retrofitting has focused mainly on reducing the operational energy use and from a technological perspective. Less is known about the impact from embodied energy generated in the building process and during operation. An area that lacks of research is how buildings are actually being used (Gram-

Hanssen, 2013). Users play an important role as unpredicted or changed behavioural patterns may outweigh efficiency improvements in the building with respect to both energy and material use (Buhl, 2014; Hertwich, 2005; Liedtke, et al., 2012). There is a need to understand the social practices that lie behind sustainable behaviours (Maller et al., 2012).

The questions that are investigated in this paper thus encircle two main areas. Firstly, how can we create a circular kitchen design that adapts to the users' needs over time and that also promotes a sustainable lifestyle? Secondly, how can this knowledge of user behaviour be integrated into the broader retrofitting agenda?

1.2. Method and approach

The research is part of a European collaboration called "The Circular Kitchen". The project has a transdisciplinary setting involving two academic institutions in the Netherlands and Sweden and industry stakeholders in both countries with different relations to the kitchen (a private Swedish housing developer, Dutch social housing associations, kitchen producers, one in each country, and an appliances producer). More stakeholders for a circular system are to be added. In Sweden, the project also involves a living lab with permanent residents that offers the preconditions for user studies and tests. The aim is to create a first circular kitchen prototype by the end of 2018 and a second in 2019. The prototypes will be tested, evaluated and further developed, in collaboration with different stakeholders. The final aim is to have a market-ready product that will be used in new housing as well as in housing retrofitting on a larger scale by 2021. In this paper, we focus on the Swedish part of the project.

This paper is based on literature reviews, a number of workshops with industry partners in the team and a first set of insights studies among users in the living lab facility. Work is in progress and we can merely present very early results in this paper.

2. RESULTS

The research project involves both "knowledge first" and "process oriented" activities such as developing a common problem definition and co-create new knowledge (Lang et al., 2012). The knowledge first part consists on developing more scientific knowledge on the one hand on material and climate impact of the kitchen, on the other hand on user behaviour in relation to kitchen practices (use and maintenance). The process part consists on how to combine different knowledge in the project team in order to identify weaknesses in the supply chain, and to create new products that are taken up and used by the stakeholders.

As a starting point, user insight studies were performed among residents in the living lab. The same kind of insight studies are also planned with other target groups and kinds of housing. Methods used were on-line surveys, deep interviews, positioning tags carried by residents and placed on cabinets and appliances, as well as sensors measuring the energy and water consumption in the kitchen. The insight studies provide us with knowledge on how the kitchens are used today, to what extent they support users in performing everyday activities and how sustainable practices may be fostered or hindered by certain properties of current kitchen designs.

Results from the user insight studies showed that the kitchen was referred to as a social area where the living lab residents would most frequently hang out. Potential to increase the support for sustainable behaviour were also found, mainly in terms of providing a better storage system for different kinds of waste. Some improvements in the function of appliances were also suggested by the participants as well as changes in the layout of the kitchen in order to support a better workflow in different kitchen activities and better possibilities to utilise the kitchen as a "living area".

Apart from climate impact studies and user insight studies, analysis of process and supply chains for kitchen and appliances producers will be important activities. It is necessary to simultaneously work on an industrial model and a business model in order to shift the current unsustainable situation into a more circular system where the prototype can become a viable solution. Insights in the processes and supply chain will be generated from workshops. Together with the industry partners, materials, production lines, and stakeholders will be mapped and analysed in order to detect where improvements can be made.

Finally, the take-up of the new kitchen among housing developers and housing associations will be supported. In order to get a broad implementation of the new kitchen model, it also has to fit the production and business models of the building industry in new production and in renovation.

3. PRACTICAL AND MANAGERIAL IMPLICATIONS

Our time of rapid urbanisation confronts cities across the globe with numerous challenges associated with the provision of quality housing to be both environmentally and socially sustainable. There is thus a growing demand for retrofitting solutions for enormous quantities of existing housing stock. In order to establish and accommodate the transition towards more sustainable, liveable and smarter housing, public organisations, industry and civil society need to work together on innovative solutions. There is a need for a new take on retrofitting and circularity, taking user needs as a starting point. The research points towards that reconsideration is needed in retrofitting approaches to involve the users' perspective, which should be a target-setting aspect. The building sector, as well as researchers that work on renovation, need to shift their attention from merely technological improvements to an understanding of liveability of dwellings and the implication for long-term sustainability of stock.

FURTHER READING

Will be added after peer-review

REFERENCES

Buhl, J. (2014). Revisiting Rebound Effects from Material Resource Use. Indications for Germany Considering Social Heterogeneity. *Resources*, *3*(1), 106–122. doi.org/10.3390/resources3010106

European Environment Agency. (2017). Circular by design. Copenhagen

Femenías, P., Holmström, C., Jonsdotter, L., & Thuvander, L. (2016). Arkitektur , materialflöden och klimatpåverkan i bostäder, E2B2 2016:1, Stockholm

Gram-Hanssen, K. (2013). Efficient technologies or user behaviour, which is the more important when reducing households' energy consumption? *Energy Efficiency*, *6*(3), 447–457. doi.org/10.1007/s12053-012-9184-4

Hertwich, E. (2005). Consumption and the rebound effect - An industrial ecology perspective. *Journal of Industrial Ecology*, *9*(1–2), 85–98. doi10.1162/1088198054084635

Lang, D., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, 7(1): 25-43.

Liedtke, C., Jolanta Welfens, M., Rohn, H., & Nordmann, J. (2012). LIVING LAB: User-driven innovation for sustainability. *International Journal of Sustainability in Higher Education*, *13*(2), 106–118. doi.org/10.1108/14676371211211809

Maller, C, Horn, R, Dalton T (2012) Green renovations: Intersections of daily routines, housing aspirations and narratives of environmental sustainability. *Housing, theory and practice. 29 (3)* doi:10.1080/14036096.2011.606332

Swedish Government (2017). Circular economy and biobased economy [Cirkulär och biobaserad ekonomi]. Retrieved from http://www.regeringen.se

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Assessments for selecting favourable concepts for building renovation with prefabricated elements

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ABSTRACT

Abstract – Assessments for identifying favourable building renovation concepts with prefabricated elements were carried out in six European countries within the EU Horizon 2020 project MORE-CONNECT. The identified renovation concepts allow to significantly reduce primary energy use and greenhouse gas emissions, yet are not in all cases cost-effective with respect to the reference case. Results suggest there is a need for further research to bring down costs by exploiting the upscaling potential of building renovation through prefabricated elements.

Keywords: cost-effectiveness; building renovation; prefabricated elements

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1. INTRODUCTION

The purpose of this paper is to give an overview on assessments carried out to select favourable building renovation concepts with prefabricated elements in the EU Horizon 2020 MORE-CONNECT project which were tested in pilot projects.

2. METHODOLOGY

For carrying out the assessments, a life-cycle approach was applied with respect to determining costs, primary energy use and greenhouse gas emissions of various building renovation concepts.

To correctly determine the impacts of the renovation packages with MORE-CONNECT solutions on costs, primary energy use and greenhouse gas emissions, it is necessary to define a common reference renovation case as it would be carried out if no energetic renovation with MORE-CONNECT solutions was implemented. This reference renovation is called «anyway renovation». It comprises the restoration of the functionality of the renovated building elements, yet without improvement of their energy performance. The renovation packages taken into consideration are then compared to this «anyway renovation».

3. RESULTS

3.1. Czech Republic

The following was found from the assessment carried out in Czech Republic for the investigated reference building:

For the identification of a favourable building renovation concept in Czech Republic, among others various variants of wall insulation were investigated. Compared to the reference case, they all decreased greenhouse gas emissions burden by about 40 %. The MORE-CONNECT solution with 10 cm of main insulation layer had similar environmental impact as 30 cm ETICS but showed higher price by about 12 %. The MORE-CONNECT solution with 20 cm of main insulation showed slightly lower environmental impact than the 10cm MORE-CONNECT solution with almost the same cost in case of plastic frame windows. Aluminium frames were connected with higher costs by 4 %, wooden frames were the most expensive ones (costs higher by 14 % compared to plastic frames). The MORE-CONNECT solution containing vacuum insulation layer throughout the panel (to reach better insulation parameters without significant increase in thickness) showed noticeably higher cost with only negligible decrease in primary energy use or greenhouse gas emissions.

The results indicate that the MORE-CONNECT solution for walls may be comparable to ETICS with EPS. The prices were found only slightly higher in the case of MORE-CONNECT panels, while ETICS resulted with higher greenhouse gas emissions. Therefore, MORE-CONNECT panel with 20 cm of main thermal insulation and plastic-frame windows was considered to be the optimal solution for walls. This solution means 42% reduction of primary energy, 43% reduction of GHG emissions and 25% save of yearly costs compared to the reference case (“anyway” renovation).

Furthermore, the following measures were included in the renovation package selected as favourable concept for implementation in the pilot project: The attic floor is provided with 40 cm of blown wood fibre insulation, 14 cm of additional mineral wool insulation are used in the basement, new triple-glazed windows are installed with plastic frames and U-value for the entire window of 0.7 W/(m2K), and a ventilation system connected with warm-air heating.

3.2. Denmark

The following was found from the assessment carried out in Denmark for the investigated reference building:

The energy renovation concept development calculations performed for four heating systems shows that nZEB targets can be reached for all of these heating systems. Only for the case with an oil burner as heating supply system can this be done directly cost-effectively – that is with the same or reduced total costs compared to the reference case. However, when considering a financial value of co-benefits from the energy renovation all cases are cost-effective.

The favourable concept which was selected in the MORE-CONNECT project comprises the following elements:

- The roof is insulated with 30 cm of mineral wool.
- The wall is insulated with 20 cm of mineral wool.
- The windows are replaced by 3-layer low energy windows
- A balanced mechanical ventilation system with a high efficiency heat recovery is installed combined with new sealing to obtain increased airtightness of the building

- 2 m² thermal solar collectors per apartment are installed
- 5 m² PV system per apartment is installed

3.3. Estonia

The following was found from the assessment carried out in Estonia for the investigated reference building:

Renovation solutions were selected in order to achieve the nZEB energy efficiency level (EPC class A). nZEB level requires also on-site renewable energy production in addition to the reduction of energy consumption. The heat source for the investigated building is district heating. It was not changed, because in the district heating area it is obligatory to use district heating as a heat source.

The favourable concept which was selected in the MORE-CONNECT project comprises the following elements:

- The wall is insulated with a MORE-CONNECT prefab element including 30-35 cm of insulation;
- The roof is insulated with MORE-CONNECT prefab element including 30 cm of insulation;
- New triple glazing windows were installed into element if factory conditions;
- Installation of HVAC engine: supply-exhaust ventilation system with heat recovery;
- On the roof are installed 100 m^2 solar collectors for domestic hot water and 90 m2 PV panels (10 kW).

3.4. Latvia

The following was found from the assessment carried out in Latvia for the investigated reference building:

For the identification of favourable concepts, an assessment of various possible renovation packages was carried out. Totally nine different packages were evaluated. Regarding the heating system, it was found that the most cost-effective solution are heat pump and wood systems. There are two main reasons why heat pump and wood systems weren't chosen: existing legislations requires that buildings connected to existing district heating keep their connection to the district heating grid; installation of heat pump underground loop requires extra permission from local authorities and a plot of land owners.

The favourable concept which was selected in the MORE-CONNECT project comprises the following elements:

- As heating system, the existing district heating system is chosen. It has the second lowest primary energy use and reasonably low CO_2 emission values.
- Wall insulation with prefabricated panel including 20 cm mineral wool was chosen as the solution which allows significant energy savings with optimal life cycle costs.

In the investigated building, the attic slab already is insulated by 20mm mineral wool. Only minor repair works are necessary to restore existing attic thermal insulation. Cellar ceiling insulation wasn't taken into consideration since the cellar height in the investigated building is small and an extra layer of insulation would significantly reduce space height.

3.5. Netherlands

The following was found from the assessment carried out in the Netherlands for the investigated reference building:

An 80 % reduction of primary energy use can be achieved with a package of measures for deep renovation of the building, including a MORE-CONNECT prefabricated element.

This is possible for all three of the investigated heating systems, natural gas, heat pump, and wood pellets. All of these far-reaching renovation packages were found to be cost-effective with respect to the reference case. In terms of emissions, the renovation package with wood pellets is the most favourable option. However, there are some practical considerations in the Netherlands with wood pellets.

The favourable concept which was selected in the MORE-CONNECT project comprises the following elements:

- The wall is insulated with a MORE-CONNECT prefab element including 28 cm of mineral wool;
- The roof is insulated with MORE-CONNECT prefab element including 28 cm of mineral wool;
- The ground floor is additionally insulated with PUR insulation (U = 0.22 W/m2K);
- New windows are installed with U-value of 0.8 W/m2K (triple glazing);
- Installation of HVAC engine: supply-exhaust ventilation system with heat recovery;
- On the roof are installed 40 m2 PV panels (6.4 kWp).

3.6. Portugal

The following was found from the assessment carried out in Portugal for the investigated reference building: the most significant measures improving the energy performance of the building are the replacement of the domestic hot water (DWH) and HVAC systems and the addition of insulation to the exterior walls. Currently, the prefabricated panel developed in the scope of MORE-CONNECT project presents very high investment costs because it does not have yet an optimized assembly line developed for mass production, which affects the cost-effectiveness of the solution. However, with the foreseen optimization of the prefabrication system, the cost of the panels can be reduced by about 70% when compared with the actual values, making the solution much more attractive to the market.

Based on the assessment carried out, the selection of the favourable concept does not change with respect to the envelope of the building when considering the embodied energy and embodied carbon emissions of the materials used. The favourable concept which was selected in the MORE-CONNECT project comprises the following elements:

- Installation of the optimized prefabricated module together with a 10 cm layer of mineral wool to be applied between the pre-existent exterior walls and the prefab module;
- 6 cm added insulation to the roof and cellar;
- Biomass boiler for heating and DWH.

4. CONCLUSIONS

Favourable concepts were identified which significantly reduce greenhouse gas emissions and primary energy use with prefabricated elements in all geo-clusters covered by the MORE-CONNECT project. Whereas selected favourable concepts were often cost-effective in comparison with related reference cases, it was also often observed that the costs of the prefabricated elements are currently higher than those of conventional renovation solutions. However, due to the possibilities for upscaling of the industrialized processes for producing the prefabricated panels, there is a potential that costs can be further brought down to make building renovation concepts with prefabricated elements more cost-effective in the future.

FURTHER READING

We acknowledge that extend abstracts can be limited in scope or link to ongoing research projects. Therefore, we invite authors to reference ‘further reading’ publications including websites and briefly summarize ongoing work.

** At the proposal stage, please do not put identifiers in this section.*

REFERENCES

Insert your references here; references must follow the Harvard Referencing System.

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Energy efficiency of dwellings: a risk factor to comfort and health? An analysis of 8 case study dwellings

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ABSTRACT

Abstract – The existing housing stock needs to be retrofitted conform the current energy efficiency criteria to meet the international climate goals. However, measures to improve energy efficiency can negatively affect the indoor environment. In the current paper we address the indoor environmental related risk factors. Also, we provide recommendations on how to avoid comfort and health issues when applying energy saving measures. Retrofitting dwellings should be done from an integral point of view considering both the implications on energy use and its effect on health and comfort of the residents.

Keywords: Residential ventilation; Sick Building Syndrome; Indoor environmental quality

1. INTRODUCTION

The Paris agreement (United Nations, 2015) forces policy makers worldwide to reduce CO_2 emissions to keep the global temperature rise below 2°C. To achieve this, the total energy consumption needs to be reduced and the share of renewable energy sources needs to be increased. Since buildings are responsible for about 40% of the worldwide energy use sector (Pérez-Lombard, et al., 2008), this is an important target sector. The Energy Performance of Buildings Directive (2010) and the Energy Efficiency Directive (2012) are the main EU instruments promoting energy performance of buildings in the EU (European Commission, 2018). Strategies include high insulation values for buildings and an airtight building envelope. In dwellings this often means that conventional natural ventilation is replaced by mechanical ventilation to ensure sufficient ventilation rates and to be able to use heat recovery. Due to the increased airtightness and insulation values of these buildings, adequate functioning of the ventilation systems is of major importance for the indoor air quality and thermal comfort. A Dutch field study in 150 newly built houses with mechanical ventilation showed that there are many problems with the design, install, use and maintenance of the residential ventilation systems (Balvers, et al., 2012). These problems can, among others, result in building related symptoms and overheating of dwellings. New concepts for heating, cooling and ventilation in dwellings require different design considerations and change the way residents should use the house. Improving the indoor climate and thereby end-user satisfaction in energy efficient buildings is essential to increase the acceptance of residents towards energy efficient housing (Mlecnik, et al., 2012). In this paper we provide an overview based on 8 cases of energy efficiency measures that are common in Dutch dwellings and the related indoor environmental problems. Two case studies are used to identify specific risk factors.

2. METHODS

To obtain a better understanding of the current problems, we analysed a selection of 8 Dutch cases in which dwellings were provided with energy efficiency measures and in which indoor environmental related complaints were reported afterwards. Using the BBA database between the year 2000 and 2017, 8 cases were selected. These cases met de following criteria: indoor environmental problems, modern dwellings (>2003) and sufficient information on the building characteristics. For each case, the energy efficiency measures that were applied were listed as well as the complains that were reported. The most frequently reported problems were highlighted. After that, two cases were selected to identify the specific risk factors for the most frequently reported problems related to the energy efficiency measures. Based on these risk factors, recommendations are made for the design and use phase, to prevent problems in future energy efficient dwellings.

3. RESULTS & DISCUSSION

Of the 8 cases that were selected, 1 case considers a renovated dwelling (#5), while the others newly built dwellings constructed after 2005 (Table 1). Most dwellings are provided with a mechanical supply and exhaust system (6 out of 8) and have a high insulation value of the façade (≥ 2,5 m²*K/W). Complaints that were reported were mainly related to overheating and building related symptoms such as a headache, irritated eyes, a dry skin and a sore throat (Table 2). Therefore, two cases were selected to identify factors which are of influence of overheating (case 6) and building related health symptoms (case 4). For each case the applied energy efficiency measures, the intended effect on indoor environmental quality and the side effects were listed (Table 3).

Table 1 Overview and characteristics of the selected projects.

Building properties	#1	#2	#3	#4	#5*	#6	#7	#8
Year of construction / renovation	2008	2009	2004	2005	2015	2012	2009	2010
Number of dwellings	1	8	1	1	1	63	1	1
High insulation (≥ 2,5 m²*K/W)	x	x	x	x	x	x	x	x
Sun protection glass						x		
Mechanical supply and exhaust ventilation	x		x	x	x		x	x
Mechanical exhaust, natural supply		x				x		
Heat recovery	x		x	x	x		x	x
Bypass ventilation system	x				x			
Heat pump		x					x	
CV Boiler				x	x	x		
District heating	x		x					x
Active cooling							x	
Floor heating		***					x	
Air heating		***			x			
Radiators	x	***	x	x				
Convectors		***				x		x

** indicates renovated dwelling. *** unknown as it was not part of the scope of the specific project.*
The cases in which only 1 dwelling was investigated, the dwelling was usually representative for many other dwellings situated in the same street or neighbourhood.

Case 6 was selected to identify factors related to overheating. The main problem was the reduced heat loss of the building due the energy saving measures: high insulation values, insufficient ventilations and insufficient operable windows. Other factors that led to overheating in this specific case were relatively high internal loads; the rooms were used as studios meaning continuous use of the same room which was both living and bedroom and hot water pipes ran through the entrance of each studio. Finally, the building was built with large glass surfaces without external blinds (sun resistant glass was used).

When applying heat loss reducing measures, attention should be paid to (temporarily) reducing internal and external heat loads to reduce the risk of overheating for example using external blinds and well-thought-out floor plans. Also, to be able to counteract accidental high indoor temperatures, the opportunity to increase heat loss should be present, for example by using operable windows and night ventilation. This example shows that energy efficient measures focus on reducing the amount of energy needed for heating. However, less attention was paid to preventing overheating.

Case 4 was selected to identify factors relating to building related symptoms. This dwelling was provided with a mechanical ventilation system with heat recovery to ensure sufficient ventilation while reducing undesired heat loss. In the current dwelling, the main cause of SBS complaints was a very low ventilation rate caused by multiply problems linked to the ventilation system. The ventilation rate was set to the lowest setting, because of noise. In one bedroom the supply grille was closed due to complaints of draft and in another bedroom no air supply was present since this was not the intended function of the room during design. Additionally, the fresh air supply duct was polluted, and it was demonstrated that there was a short circuit in the ventilations system causing contaminants from the exhaust air to mix with the fresh air.

The problems related to a balanced ventilation system relate to maintenance and the design of the ventilation system. Important to note is that a bad design leads to a higher risk of undesired user behaviour, e.g. obstruction of the air supply because of draught, reducing the ventilation rate because of mechanical equipment noise. The indoor air quality and acoustics can be improved by installing ventilation systems with a higher ventilation capacity and low noise levels. During construction, special attention should be given to keeping the ventilation system clean. After construction, occupants should be provided with good maintenance instructions to keep the ventilation system clean.

An integral approach for both improving energy efficiency and health and comfort should be deployed in the design or renovation buildings (Boerstra, 2017).

Table 2 Comfort and health problems that were reported in the different dwellings.

	Total	#1	#2	#3	#4	#5	#6	#7	#8
Thermal comfort									
Overheating	5	x				x	x	x	x
Too cold	1							x	
Draught	1				x				
Insufficient temperature influence	1							x	
Indoor air quality									
Stuffy air	1	x							
Cooking smells	2	x	x						
Mould growth	1				x				
Dry air	2				x			x	
Noise									
High mechanical equipment noise level	3	x			x				x
Building related symptoms									
Headache	5	x	x	x	x	x			
Irritated, itchy or dry eyes	5	x	x	x	x	x			
Throat and nose related complains	3		x	x		x			
Dry or itchy skin	3		x		x			x	
Chronic cold	2		x			x			
Unusual sleepiness	2	x	x						
Anxious	2	x			x				

Table 3 Two commonly applied energy efficiency measures, their intended effects and their side-effects.

Case	Energy efficiency measure	Intended effect(s)	Side effect(s)
#6	High insulation values and air tight facade.	Reduced heat loss in heating season.	Reduced heat loss in summer and mid-season.
#4	Mechanical supply and exhaust ventilation	Ensure sufficient ventilation and prevent undesired heat loss	Complexity can lead to design faults which lead to a bad indoor air quality.

CONCLUSION

The results show that energy efficient measures in newly built and renovated houses can negatively affect the indoor environment. Overheating, building related symptoms complaints and installation noise are commonly observed. During the design and in use attention should be paid to prevent these side-effects and to simultaneously improve energy efficiency and indoor environmental quality in retrofitted houses.

REFERENCES

Balvers, J. et al., 2012. Mechanical ventilation in recently built Dutch homes; technical shortcomings, possibilities for improvement, perceived indoor environment and health effects. *Architectural Science Review,* 55(1), pp. 4-14.

Boerstra, A., 2017. Towards HEAnZEBs!. *REHVA,* Issue 3, p. 5.

European Commission, 2018. *Energy Efficiency, Buildings.* [Online] Available at: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

Mlecnik, E. et al., 2012. End-user experiences in nearly zero-energy house. *Energy & Buildings,* 49, pp. 471-478.

Pérez-Lombard, L., Ortiz, J. & Pout, C., 2008. A review on buildings energy consumption information. *Energy and Buildings,* 40(3), pp. 394-398.

United Nations, 2015. *Climate Get the Big Picture.* [Online] Available at: http://bigpicture.unfccc.int/#content-the-paris-agreemen

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Modular prefab integrated HVAC units

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ABSTRACT

Building service systems of existing residential buildings need reconstruction to provide indoor air quality, thermal comfort, and quality of life for occupants. In order to minimize installation costs and time as well as to ensure installation quality and simple modernization during lifetime, the multifunctional modular HVAC unit "house engine" is presented in this paper.

Keywords: HVAC, modular units, duct

INTRODUCTION

To provide indoor air quality, thermal comfort, and quality of life for occupants, all apartment buildings as well as single family houses have such vitally important building service systems as heating system, hot water system, ventilation and cooling system (depending on climate and architecture). Use of renewable and sustainable energy is one of the EU top priorities in order to ensure significant reduction of greenhouse gas emission and decarbonise the building stock (EPBD 2018).

Indoor climate of existing residential buildings is lower than required and expected in different climatic regions in Europe (Kylili et al. 2016; Terés-Zubiaga et al. 2013; Mikola et al. 2017) and needs improvement. The designed service life of existing service systems is ended or close to the end. Therefore building service systems need reconstruction. Usually building service systems are installed separately in different technical rooms, shafts or in some cases even floors or ceilings. Additional installation of building service and renewable energy systems during deep energy renovation may require significant reconstruction of apartments and existing service system.

In order to minimize installation costs and time as well as to ensure installation quality and simple modernization during lifetime, the multifunctional modular HVAC unit "house engine" and installation of service systems into prefabricated modular insulation elements is presented in this paper.

HVAC "HOUSE ENGINE"

House engine is a compact energy unit which easily can be connected to such building systems as heating, ventilation, hot water supply and cooling. Due to its compact form, the initial design of house engine should include possible options for future upgrade. Identifications of house engine optional components is shown in Figure 1.

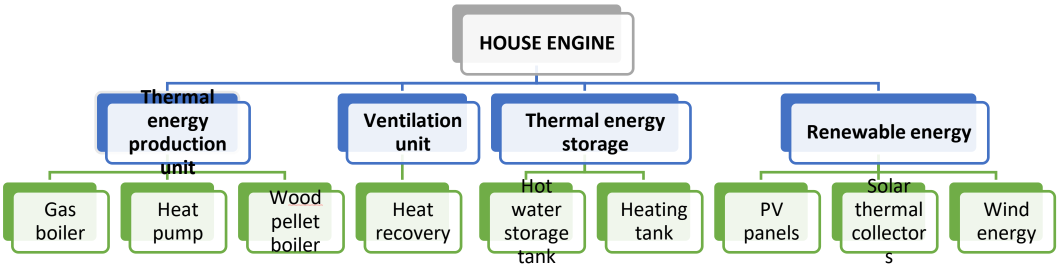


FIGURE 1 HVAC SYSTEMS "HOUSE ENGINE" OPTIONAL COMPONENT

The modular solutions of a house engine for renovation of a terrace house in Netherland is shown in Figure 2. The main benefits are short installation time, indoor space optimizations, noise reduction, easy maintenance etc.

a) 24kW natural gas HVAC units

b) already existing solutions, Nederland

c) possible dimension of 24kW natural gas HVAC units

FIGURE 2 MODULAR HVAC UNITS FOR ROW HOUSE

Also, some possible modification could include installation of district heating sub-station.

INSTALLATION OF SERVICE SYSTEMS INTO PREFABRICATED MODULAR INSULATION ELEMENTS

The modular pipe units can be used to reduce on-site installation time (Figure 3). Installation of ventilation pipe into external wall saves a lot space in apartment and minimize disturbance of occupants. By placing the ventilation ducts inside the insulation part of external envelope the U-value is reduced, this means that the ducts should not be too large, or the insulation layer must be sufficient. At the same time knowing that the ventilation ducts are outside the building envelope the allowed air velocity in them could be increase compared to situation when they are placed inside the rooms. Embedded water pipes have a several disadvantages, such as high risk of leaks.

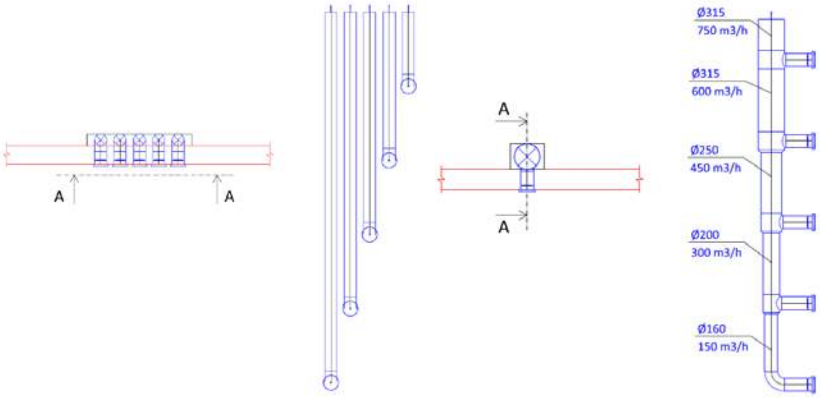
a) water and gas pipe prefabricated solution

b) ventilation ducts installation in insulation element

b) ventilation duct connectors

FIGURE 3 MODULAR PIPE INSTALLATION

Two main different approaches of supply air duct design are used in practice. The first approach (Figure 4a) is when each apartment has a separate duct, which is coming from the main branch near the AHU. The second approach is with one main raiser that gradually decreases in size starting from top to bottom floor (Figure 4b). To reduce noise movement between apartments through ventilation ducts, installation of noise dampeners is needed. Technical solution requires higher diameters, thus causing reduction of thermal insulation layer thickness.



a) separate ventilation duct risers

b) one main ventilation duct riser

FIGURE 4 VENTILATION DUCT RISERS

In all ventilation approaches noise dampeners should be installed. Due to the low scale noise dampeners are not shown in Figure 4.

CONCLUSIONS AND FUTURE READINGS

Potential integration of renewable energy sources into renovation process is a major issue to approach the nZEB status. The possible principles of “house engine” are described and the main possibilities of them described. It is believed that they can be the future of engineering systems and serve as the heart of the house. Especially in cases of renovation when all the systems need to be made compact while connected to existing networks. They must include all the basic equipment such as heat exchanger for heating systems connection, hot water heat exchanger, local energy source, expansion tanks and all the necessary valves, air handling unit with heat recovery section and in some cases even cooling source.
Some already implemented HVAC engine solutions installation of service systems into prefabricated modular insulation elements have shown good potential for future implementation (MoreConnect 2016, https://www.more-connect.eu/)

REFERENCES

EPBD, 2018. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. Official Journal of the European Union.

Kylili, A., Fokaides, P.A. & Lopez Jimenez, P.A., 2016. Key Performance Indicators (KPIs) approach in buildings renovation for the sustainability of the built environment: A review. Renewable and Sustainable Energy Reviews, 56, pp.906–915.

Mikola, A., Kalamees, T. & Kõiv, T.-A., 2017. Performance of ventilation in Estonian apartment buildings. In Energy Procedia, 132, pp. 963-968.

Terés-Zubiaga, J. et al., 2013. Field assessment of thermal behaviour of social housing apartments in Bilbao, Northern Spain. Energy and Buildings, 67, pp.118–135.

MoreConnect, 2016. Modular prefab integrated HVAC units: description and development of demonstration units Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular REtrofitting and CONNECTions (MORE-CONNECT): https://www.more-connect.eu/wp-content/uploads/2018/04/Modular-prefab-integrated-HVAC-units-description-and-development-of-demonstration-units.pdf.

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Are energy decisions about energy?

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ABSTRACT

The most challenging element of the energy transition is to reduce fossil fuel energy consumption in the existing housing stock because of the complexity of the system of different actors and their social practices. In this research an interdisciplinary socio-technical approach is used that goes beyond technology and individual behaviour and will also tackle the physical, economic and social context of the different actors. Empirical data is collected in the case-study of Parkstad Limburg (NL) and the results are used to develop recommendations to improve the effectiveness of energy transition policies and product offerings to residents.

Keywords: housing stock; energy renovation measures; interdisciplinary socio-technical approach.

1. INTRODUCTION

To meet the Paris' climate agreements (United Nations, 2015) fossil energy use and CO_2 production must be decreased radically and as a consequence buildings should use 80% less energy in 2050 (Dean et al., 2016, Wijngaart et al., 2014). To achieve this in the Netherlands, 75% of the Dutch houses need to be renovated (Rijksoverheid, 2016) with a pace of 300,000 houses each year (Wijngaart et al., 2014). This can be realised by energy renovation measures such as insulation, high efficiency glazing, efficient heating and ventilation systems and renewable energy production. Despite this technical potential and widespread policies for supporting energy renovations (Wilson et al., 2015), the energy renovation pace is not on schedule to meet the emission targets (NRP, 2015).

2. THEORETICAL FRAMEWORK

A significant amount of research is done to gain more insight in homeowners' choices regarding energy renovation measures from different perspectives and disciplines. On the one hand, techno-economic studies have identified important factors and motivations which influence choices homeowners make about energy renovations, such as financial and demographic factors and physical context (Carroll et al., 2016, Mortensen et al., 2016, Nair et al., 2010, Sardianou and Genoudi, 2013, Banfi et al., 2008, Moula et al., 2013, Poortinga et al., 2003). On the other hand, social science and psychology show that individual behaviour towards pro-environmental behaviour depends on a large number of factors such as norms and values, habits, experiences, knowledge, awareness and context (Steg et al., 2015) but these variables may differ for different energy related choices (Stern, 2014). Furthermore, social science studies are mainly focused on daily energy saving behaviour and less on high-impact energy renovation measures (Stern, 2014, Wilson and Dowlatabadi, 2007, Abrahamse et al., 2005).

Overall, previous literature review demonstrates the need for a more comprehensive understanding about homeowners' choices for energy renovation measures, one that goes beyond the economics of energy choices, awareness, attitudes and behavioural control. This understanding is required to improve the effectiveness of energy transition policies and product offerings to residents (Wilson et al., 2015, Steg et al., 2015). Therefore, this research uses an interdisciplinary socio-technical approach to collect empirical data, one that goes beyond technology and individual behaviour but will also tackle the physical, economic and social context of homeowners. In addition, it will highlight the role of advice in the decision making process, especially from people in their social network which is a topic that is not widely researched.

3. METHOD

In this study, a mixed method is used to collect empirical data from three Dutch projects where energy audits were offered to private homeowners. The projects are initiatives from municipalities in the city region of Parkstad Limburg. This region has been selected since it is one of the frontrunners on energy strategies in the Netherlands (VNG, 2018). It locates eight municipalities and counts 125,885 households (Stadsregio Parkstad Limburg, 2016). This research focuses on owner-occupied homes because this group forms the majority: 53% in Parkstad (Delheij et al., 2014) and 70% on average across the EU (Eurostat, 2018). Data was collected by online questionnaires (n=91) and face-to-face interviews (n=52) with homeowners who have recently carried out energy renovation measures and homeowners who have not done so, to get both perspectives (Wilson et al., 2015). The interviews followed a semi-structured format, based on the literature review, with mostly open-ended questions. The questions covered details about: their experiences, motivations and barriers, role of advice, future plans, what the municipality can do to help them and also background information was collected. The interviews were digitally recorded, transcribed, and qualitative analysis software (Atlas.ti 8) was used to systematically analyse the transcripts using different coding techniques (Evers, 2016).

4. RESULTS

The findings of this study show a complex system with a wide range of interlinked factors which influence homeowners' choices for energy renovation measures. The degree of environmental concern is a factor but also physical aspects like the home itself and the technology used. Next, financial factors play a role, like increasing marketability of the home or a barrier, the high investment costs. Also organisational factors, like inconvenience and guarantees influence homeowners' decisions. Furthermore, demographics seem to influence some of these factors. In addition to these factors, the role of advice plays an important role in the decision making process of homeowners. They appreciate the objective advice organised by municipalities, personal contact with companies and their social network seems to be an important advisor in their decision making process. On the other hand, homeowners also share their own experiences in their social network.

These findings will be discussed in focus groups with policy makers and companies in follow-up research to develop policy recommendations and recommendations for effective product offerings to residents.

5. CONCLUSION

This study shows that energy renovation decisions are not about energy in a simple way but that energy renovation choices are being assessed by homeowners from various perceptions. The findings reveal new entry points for policy action and combined actions seem to be the most effective; First, offering credible advice focused on the specific situation of homeowners, their individual needs and preferences and taking the multiple benefits into account; Second, organising the implementation of energy renovation measures by skilled and trustworthy companies (less inconvenience or hassle for the homeowner); Third, offering several financing and guarantee options from the local government and fourth, supporting the sharing of homeowners' experiences in social networks.

REFERENCES

ABRAHAMSE, W., STEG, L., VLEK, C. & ROTHENGATTER, T. 2005. A review of intervention studies aimed at household energy conservation. *Journal of environmental psychology,* 25**,** 273-291.

BANFI, S., FARSI, M., FILIPPINI, M. & JAKOB, M. 2008. Willingness to pay for energy-saving measures in residential buildings. *Energy economics,* 30**,** 503-516.

CARROLL, J., ARAVENA, C. & DENNY, E. 2016. Low energy efficiency in rental properties: Asymmetric information or low willingness-to-pay? *Energy Policy,* 96**,** 617-629.

DEAN, B., DULAC, J., PETRICHENKO, K. & GRAHAM, P. 2016. *Towards zero-emission efficient and resilient buildings. Global Status Report*, GABC.

DELHEIJ, V., VAN DER STRATEN, R., STREMKE, S., OUDES, D., BROERS, W., KIMMAN, J., BONGERS, J., JANSSEN, F., WEUSTEN, P. & HUGTENBURG, J. 2014. *Ambitiedocument Parkstad Limburg Energie Transitie (PALET),* Heerlen, Stadsregio Parkstad Limburg.

EUROSTAT. 2018. *Housing statistics* [Online]. Eurostat. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Housing_statistics [Accessed 7 February 2018].

EVERS, J. 2016. *Kwalitatieve analyse: kunst en kunde,* Amsterdam, Boom uitgevers.

MORTENSEN, HEISELBERG, P. & KNUDSTRUP, M. 2016. Identification of key parameters determining Danish homeowners' willingness and motivation for energy renovations. *International Journal of Sustainable Built Environment,* 5**,** 246-268.

MOULA, M. M. E., MAULA, J., HAMDY, M., FANG, T., JUNG, N. & LAHDELMA, R. 2013. Researching social acceptability of renewable energy technologies in Finland. *International Journal of Sustainable Built Environment,* 2**,** 89-98.

NAIR, G., GUSTAVSSON, L. & MAHAPATRA, K. 2010. Factors influencing energy efficiency investments in existing Swedish residential buildings. *Energy Policy,* 38**,** 2956-2963.

NRP 2015. *Energetische renovatie van Woningen, goed voor Nederland,* De Meern, NRP Spaar het Klimaat.

POORTINGA, W., STEG, L., VLEK, C. & WIERSMA, G. 2003. Household preferences for energy-saving measures: A conjoint analysis. *Journal of Economic Psychology,* 24**,** 49-64.

RIJKSOVERHEID 2016. *Cijfers over wonen en bouwen 2016,* Den Haag, Het ministerie van Binnenlandse Zaken en Koninkrijksrelaties,.

SARDIANOU, E. & GENOUDI, P. 2013. Which factors affect the willingness of consumers to adopt renewable energies? *Renewable energy,* 57**,** 1-4.

STADSREGIO PARKSTAD LIMBURG. 2016. *Parkstad monitor* [Online]. Heerlen: Stadsregio Parkstad Limburg. Available: https://parkstad-limburg.buurtmonitor.nl/ [Accessed 4 August 2017].

STEG, L., PERLAVICIUTE, G. & VAN DER WERFF, E. 2015. Understanding the human dimensions of a sustainable energy transition. *Frontiers in psychology,* 6.

STERN, P. C. 2014. Individual and household interactions with energy systems: toward integrated understanding. *Energy Research & Social Science,* 1**,** 41-48.

UNITED NATIONS 2015. *Paris Agreement, FCCC/CP/2015/L.9/Rev.1,* Paris, UNFCCC secretariat.

VNG. 2018. *Energietransitie en herstructurering woningen in Parkstad* [Online]. Den Haag. Available: https://vng.nl/onderwerpenindex/milieu-en-mobiliteit/energie-en-klimaat/nieuws/energietransitie-en-herstructurering-woningen-in-parkstad [Accessed 10 September 2018].

WIJNGAART, R. V. D., FOLKERT, R. & MIDDELKOOP, M. V. 2014. *Op weg naar een klimaatneutrale woningvoorraad in 2050. Investeringsopties voor een kosteneffectieve energievoorziening,* Den Haag, Planbureau voor de Leefomgeving,.

WILSON, CRANE & CHRYSSOCHOIDIS 2015. Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. *Energy Research & Social Science,* 7**,** 12-22.

WILSON, C. & DOWLATABADI, H. 2007. Models of decision making and residential energy use. *Annu. Rev. Environ. Resour.,* 32**,** 169-203.

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New scalable modular robot for on-site construction work

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ABSTRACT

Abstract – within the EU Horizon 2020 MORE-CONNECT project a robot has been developed for concrete 3D printing on the building site. It is a new product-platform (combination of existing hardware technologies but a totally new software control system), that significantly change the the whole work process from drawing to finished task, which it drastically changes, automate, and improve.

Keywords: robot; 3D printing; quality control;

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1. INTRODUCTION

Today, the construction industry lack up to 40% of the labour needed in the renovation and the new build demand in Europe towards 2040. With manual and labour intensive work processes, the construction industry desperately needs solution able to optimize and automate. Currently, implementation of robots in the construction sector is approximately 0,2%.

Robot At Work has developed state-of-the-art modular robot platform for the construction industry that can work from 1m2 to 60m on-site and has a multifunctional use, which means it can be integrated in many different kinds of task. The robot platform can operate with different kinds of tools: e.g., spray-painting, spraying mortar/ putz for rendering, milling, 3D printing on ground or facade with any material, moving or lifting materials, cutting of different types of plates. The flexibility of the robot platform makes it possible to make easy onsite reconfiguration, which gives the entrepreneur and/or craftsmen the opportunity to use the robot to perform different task and processes on the construction site.

The modular robot is controlled by an intuitive tablet/smartphone-based interface making it possible for construction worker to setup the robot and start, pause, and stop a preprogramed work package.

For the first time ever, our solution makes it possible for an on-site robot to execute exactly what has been drawn and planned by the architect in cooperation with the craftsman ensuring better workflows, quality, and minimizing inaccuracies. Our modular robot will be able to save labour time on-site from 10% up to 80% depending on the task and processes performed

Robot at Work aims at a rapid and scalable market introduction with essential strategic partners within different technical sectors of the construction industry. The goal is to make different strategic partners and end-customers able to easily apply the modular robot to whatever task or process they want to automate.

2. CHARACTERISTICS AND FEATURES

The core distinctive innovative element of the new modular and scalable robot is the fact that it is the first of it's kind on the building site. The modular robot platform can work from 1m² to 60m² (or more) on-site and has a multifunctional use which means it can be integrated in many different kinds of task on site, because it can operate with different kind of tools for example: spray-painting, spraying mortar/ putz for rendering, milling, 3D printing on ground or facade with any material, moving or lifting materials, cutting of different types of plates. The robot uses only 230volt and the heaviest part weighs only 15kg.

The robot is controlled by an intuitive interface that operates on any platform (computer, smartphone or tablet) without installing anything on the devise. This makes it very easy for anybody to use the robot without prior training.

We managed to integrate the robot solution with the existing building process as a Plug&Play solution. The robot is programmed through purchasing of licenses to a post processor to obtain and execute from drawings generated in Autodesk or any .DXF file. Therefor a 3D scan of the building can be used for the programming of the robot.

For the first time ever, our solution makes it possible for the robot to execute exactly what has been drawn and planned by the architect. Today a detailed drawing is given to the craftsman for him to execute as good and precise as possible with his hands and knowledge.

Robot At Work makes it possible to perform with the robot exactly what was drawn and planned by the architect directly on the building. This will provide better workflows and quality for the architects and craftsmen and value for money output for the building owners.

The novel and different results compared to existing technologies are the completely new way for the robot to take over time consuming and labour intensive tasks, which therefore will liberate the worker to work on more detailed or complicated tasks. The robot will then operate as a co-worker to the craftsmen. This will generate economic value by significantly increasing the actual work output and will also reduce labour weariness for the health and social benefit of the construction worker.

Finally, the robot enables better quality control in error-prone processes on the construction site.

3. FINAL MARKETABLE PRODUCT

The final product is a new scalable modular robot with user platform for on-site work on small and large areas ready for implementation, easy to use and can be programmes directly from a drawing.

- The robot will be able to perform within the following tasks:
- Spray-painting
- Spraying mortar/ putz for rendering
- Milling
- 3D printing on ground or facade with any material
- Moving or lifting materials
- Cutting of different types of plates

Furthermore, we see big opportunities in other industries such as:

- Maintenance of surfaces on containerships

- Production of large wings for the Windmill industry.

And in general industries that perform tasks on large area.

4. CONCLUSION

The construction sector is our market. There are no robots working on-site and very few working on prefab indoor. No robot today can work on very large surfaces. Our robot can and it requires very little implementation, for each solution.

We are aiming for the the construction sector to begin implementing and experimenting with our robot just like the production industry has done for a long time, with the traditional 6 axes robots they typically use. Robot At Work is the only robot for the building sector because of its lightweight and possibility to work on large areas. Furthermore, the robot is meant to perform already existing tasks onsite with the help and knowledge of the craftsmen's expertise.

Robot At Work's modular robot platform is to be seen as a robot for implementation and use in the building industry just like the ´KUKA Robots´ or the ´Universal Robot´ is implemented to perform different tasks in the production industry. But these traditional types of robots can only work on small areas and are very heavy and not flexible and therefore not suitable for the building industry.

An elaborate presentation will be given at the conference.

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Motives and Hindrances in Energy Efficiency Renovations: Dutch Owner-occupied Sector

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ABSTRACT

Abstract – The building sector has a major share in CO_2 emission and energy consumption. In the Netherlands, 60% of the housing stock belongs to the owner-occupied sector. Since the average energy label is low and the share is high, there is a potential to reduce the energy consumption in this sector. The aim of this article is to understand the motives and hinderances of homeowners towards renovations and to find the policy implications. The WOON2012 energy module database is used and the regression analysis is conducted. The results show that the homeowners are mainly being motived by the factors of 'increasing the quality of life' and 'achieving financial benefits. The identified hinderances are 'lack of reliable expert and information', 'complexities in the work' and 'cost'.

Keywords: Motives and hinderances; Dutch owner-occupied sector, Energy Efficiency Renovations

1. INTRODUCTION

The building sector is responsible for 36% CO_2 emission and 40% energy consumption in EU. In the Netherlands, 60% of houses belong to the homeowners and the average energy label is D in this sector. Considering the high share of CO_2 emissions in the building sector and average low energy label in the owner-occupied sector, there is a considerable energy-saving potential in this sector. However, homeowners have several issues, such as financing, finding the reliable contractors, or accessing to the information (Wilson et al. 2015). For instance, the Dutch banking system offers financial support for energy efficiency renovations but the homeowners prefer to skip it due to the complexity in the procedures (Schilder et al. 2016). The purpose of this article is to evaluate the motives and hinderances for the Dutch homeowners and to investigate the policy implications. A literature review is conducted to make the theoretical framework of the motives and hinderances for the homeowners, then a WOON2012 energy module database is used to conduct the regression analysis.

2. Literature review

Evaluating motives and hinderances have been the subject of many recent studies. Wilson, Pettifor, and Chryssochoidis (2018) quantitatively analysed the homeowners' renovation process in the UK. Their results indicated that the renovations initially depend on the condition of life, and the factors influencing the renovation decision change during the renovation process. Baginski and Weber (2017) investigated the homeowners' decision-making processes of energy efficiency renovations in Germany, using a qualitative-explorative approach. They showed a high cognitive and emotional involvement of homeowners is essential. The homeowners consider several criteria in using the energy saving measures, including economic and non-economic factors such as cost-saving and thermal comfort. They concluded that the current policies in Germany need to be modified to also take the non-economic factors into account. Wilson, Crane, and Chryssochoidis (2015) demonstrated a list of motives and hinderances to EERs. They referred to the literature in the applied behavioural and sociological research, and classified hinderances and motives into commonly identified and occasionally identified. For example, the commonly identified motives are cost saving and thermal comfort, and occasionally identified motives are draughts, condensation, air quality, and property value. Jakob (2007) explored the hinderances and motives to EERs for the single-family homeowners in Switzerland. He carried out a regression analysis to evaluate the impact of influencing factors, such as age, income, household composition, construction period. In table 1, the motives and hinderances are presented.

TABLE 1. THE MOTIVES AND HINDERANCES TOWARDS THE ENERGY EFFICIENCY RENOVATIONS

Motives	Hinderances
Achieving Financial benefits Cost-saving in energy bills, Enhancing the value of the house, Selling the house easier. **Increasing the quality of life** Enhancing thermal comfort, such as Improving ventilation and reducing the moisture problems, Reducing noise. **Technical benefits** Repairing/ replacing broken equipment, Easiness to use. **Environmental concerns** Reducing energy demand to protect environment **Experiences of other people** Following other people **Program by government** Promoting energy-saving measures by public authorities	**Cost** Cost of energy-saving measures **Information** Time and efforts in finding information Past experiences/ other experiences Dissatisfaction of the past experience/ other people experiences **Credibility** Searching and finding reliable information/ experts **Support/ help** Lack of support and help, e.g., from friends, experts, etc. **Work/Process** Disruption in normal life and anticipated hassle factor **Program by government** No subsidies/loans

1. Methodology and Database

The database and the method of analysis are explained in section 3.1 and 3.2.

3.1. Database

The WOON2012 energy module database includes 4,800 houses in which 58% (2,784) is the owner-occupied sector. The database is representative of Dutch owner-occupied sector (Majcen et al. 2015; Rijksoverheid.nl 2014).

3.2. Method of analysis

The logistic regression is conducted to examine the importance of motives and hinderances on the renovation decisions. This regression is used when the dependent variable is binary (Peng et al. 2002). Our dependent variable is whether the homeowners have done the renovation in the past five years. The independent variables are the socio-demographic factors, motives and hinderances. The assumptions of the logistic regression are met, such as multicollinearity, and after running the regression, the logistic regression has been validated with multiple tests, such as goodness of fit.

2. Results

(a) The main identified categories of motives are ‘increasing the quality of life’ and ‘achieving financial benefits similar to the results of studies by [9] and [10].
(b) The main identified categories of hinderances are ‘lack of reliable expert and information’, ‘complexities in doing the energy-saving measures’ and ‘Cost’.
(c) The insignificant categories of motives are ‘technical benefits’, ‘environmental concern’, ‘experiences of other people’.
(d) The insignificant categories of hinderances are ‘past experiences’ and ‘lack of support and help from other people’.

3. CONCLUSION

This study aimed to investigate the motives and hinderances towards energy efficiency renovations by an empirical analysis of Dutch owner-occupied sector. Regression analysis shows that the critical influencing factors are the lack of reliable experts and information, time and effort to find information, and complexities in work/ process. The essential policies have been considered in the Dutch owner-occupied sector, such as providing the financial support, accessing to reliable energy providers similar to the findings by similar to the previous studies (Murphy et al. 2012; Tambach et al. 2010). The following policies needs more consideration: (a) the homeowners are mainly motivated by enhancing the quality of life rather than other factors such as financial benefits. To reduce the undermining impact of rebound effects, the policies should be designed that directly influence the occupant behaviours (Santin, 2010) (b) there are fewer programs for the information/work/process barriers compared to the financial ones, such as time and effort in applying for loans and subsidies. These policies are essential to be considered in future. For instance, the energy providers developed a program of ‘Energy Saving Explorer’. (c) One of the main barriers was the lack of reliable information, using the statistical and regression analysis. The most reliable sources of information are also identified using the statistical analysis which were the homeowners’ association, governments, environmental agencies, respectively. Therefore, the information can be distributed through these organisations.

REFERENCES

1. Wilson C, Crane L, Chryssochoidis G. Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. *Energy Res Soc Sci*. 2015;7:12-22. doi:10.1016/j.erss.2015.03.002.
2. Schilder F, van Middelkoop M, van den Wijngaart R. Energiebesparing in de woningvoorraad: financiële consequenties voor corporaties, huurders, eigenaren-bewoners en Rijksoverheid. 2016;(July):50.
3. Wilson C, Pettifor H, Chryssochoidis G. Quantitative modelling of why and how homeowners decide to renovate energy efficiently. *Appl Energy*. 2018;212:1333-1344. doi:https://doi.org/10.1016/j.apenergy.2017.11.099.
4. Baginski JP, Weber C. A Consumer Decision-Making Process? Unfolding Energy Efficiency Decisions of German Owner-Occupiers. *HEMF Work Pap*. 2017;08. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3023997. Accessed October 23, 2017.
5. Jakob M. The drivers of and barriers to energy efficiency in renovation decisions of single-family home-owners. *CEPE Work Pap Ser*. 2007;18(56):1-30. www.cepe.ethz.ch. Accessed December 12, 2017.
6. Rijksoverheid.nl. Housing Research Netherlands - Energy module. https://www.rijksoverheid.nl/onderwerpen/onderzoeken-over-bouwen-wonen-en-leefomgeving/documenten/rapporten/2012/02/24/woononderzoek-nederland-module-energie. Published 2014. Accessed February 2, 2018.
7. Majcen D, Itard L, Visscher H. Statistical model of the heating prediction gap in Dutch dwellings: Relative importance of building, household and behavioural characteristics. *Energy Build*. 2015;105:43-59. doi:10.1016/j.enbuild.2015.07.009.
8. Peng CYJ, Lee KL, Ingersoll GM. An introduction to logistic regression analysis and reporting. *J Educ Res*. 2002;96(1):3-14. doi:10.1080/00220670209598786.
9. Aune M. Energy comes home. *Energy Policy*. 2007;35(11):5457-5465. doi:10.1016/J.ENPOL.2007.05.007.
10. Mlecnik E, Straub A. Experiences of Homeowners Regarding Nearly Zero-Energy Renovations and Consequences for Business Models. *Plea 2015 Bol Archit (R)evolution*. 2015.
11. Tambach M, Hasselaar E, Itard L. Assessment of current Dutch energy transition policy instruments for the existing housing stock. *Energy Policy*. 2010;38(2):981-996. doi:10.1016/j.enpol.2009.10.050.
12. Murphy LC, Meijer F, Visscher H. A qualitative evaluation of policy instruments used to improve energy performance of existing private dwellings in the Netherlands. *Energy Policy*. 2012;45:459-468. doi:10.1016/j.enpol.2012.02.056.
13. Santin OG. *Actual Energy Consumption in Dwellings. The Effect of Energy Performance Regulations and Occupant Behaviour.*; 2010. doi:10.3233/978-1-60750-651-5-i.

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Challenges for sustainable integrated renovation: experiences from a Swedish case of a large housing estate

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ABSTRACT

The paper presents a study of the planning of a renovation of a larger Swedish housing estate that has been going on for several years with different stops and retakes. The study illustrates the challenges when planning for a renovation when external circumstances and political ambitions change over time. Sustainable renovation will be affected by value conflicts but can also be hampered by managerial and practical weaknesses in the organisation of the project. The paper is concluded with a number of recommendations for clients and consultants.

Keywords: sustainable integrated renovation; social ambitions; recommendations

1. INTRODUCTION

Challenges to reach more sustainable housing through renovation have been subject to earlier research. Energy renovations are often connected to high up-front costs, long pay-back time and attempts to make tenants pay have led to conflicts (Ástmarsson et al., 2013). Social implications of deep renovation, notably forced relocation of existing residents, has been emphasised in recent years and has become a political hot topic (Baeten et al., 2017). The fact that the housing stock with the largest needs for renovation correspond to the most socio-economic vulnerable population adds to the problem (Mangold et al., 2016). As a result, public as well as private housing companies in Sweden struggle to find socially and environmentally responsible renovation strategies (Femenías et al., 2018). Decision support are needed that fit the institutional logic of the renovation process (Gluch et al., 2018).

In this paper we present a study of a Swedish public, municipally owned housing company that attempts to find a solution for the renovation of suburban large-scale estate built in the early 1970s with 1200 apartments. Their search for a viable, sustainable and socially responsible strategy included the collaboration with the research team and the venture in a larger transformation of the neighbourhood.

1.1. Aim and method

The aim of the research has been three-fold: 1) to document the renovation process and identify important decisions, steering documents, stakeholders and their respective relations, and relate these to the outcome of the process 2) to support the housing company specifically in relation to social ambitions in the planning of the renovation, and 3) to investigate the possibilities for a sustainable renovation business model.

The study was carried out 2015 – 2017 and is based on 18 interviews with 15 different actors, observations and active participation in 19 meetings in the renovation, planning and dialogue processes encircling the transformation process (Figure 1), and the participation in a round-table discussion and three focus group meetings with representatives of the residents.

2. RESULTS

The planning of the renovation of the studied estate stretches over several years and is characterised by several stops and retakes (Figure 1). Three processes are interconnected: the planning process to produce an urban plan including densification; the renovation process of the existing buildings; and the dialogue process with the existing residents.

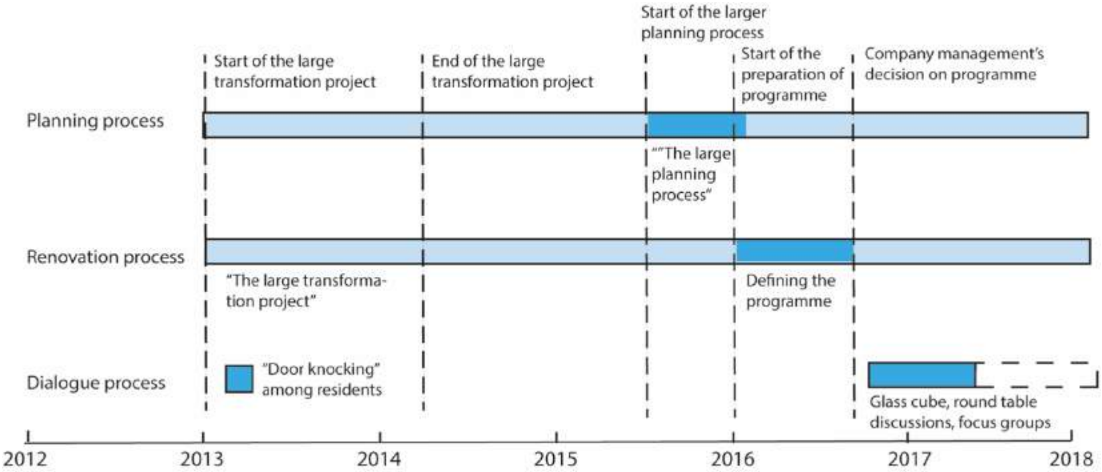

FIGURE 1. SCHEMATIC OVERVIEW OF THE PROCESSES FOR DEVELOPING THE HOUSING AREA. STUDIED PROCESSES ARE MARKED IN DARKER BLUE.

In a first phase of the renovation process, a larger reconstruction and transformation of the existing estate was planned and designed in which the tenants should be temporarily relocated. The project had high ambitions for energy-efficiency, additions to the blocks with new apartments and the rents were to increase considerably. The plan went as far as procuring a builder but it was never carried out with reference to the high costs.

In the next phase, a larger transformation of the whole area was planned together with concerned municipal agencies (planning, traffic and property development). Through new additional housing of different tenure in combination with work places, the area could increase its attractivity for investors and residents and thus create a better economic situation for the renovation. This larger planning process came to a halt as one of the agencies found the costs for the infrastructure too high and a larger risk than the city could bare despite that the area had been designated as a priority for development by the politicians.

The different stops in the process were hard to handle for the staff at the housing company. However, the buildings were in large need for renovation and another retake had to be made. Some of the staff and consultants changed workplace or got new task during the process which was a challenge for the continuity and transmission of information from earlier phases.

In a third phase, the process took a step back and a new programme for the renovation was defined. At this time the local politicians had paid attention to the negative impact of forced relocation in connection to renovation. The research team were invited to support with knowledge about integrated sustainable renovation having as a starting point a tentative model in which technical, social environmental, economic and cultural aspects of the area was to be considered. A parallel study on a sustainable business model was also initiated. In the programme several alterative solutions were proposed, finally the company's management decided upon a rather restrained and economic renovation.

Rather late in the process, a dialogue with the tenants was initiated with support from the research team. Traditionally, housing companies have been reluctant to engage with the tenants in the renovation process considering that this can lead to anxiety, conflicts and delays. In this case, the dialogue was rather structured encircling pre-defined themes and led to positive reception by the housing company. The fact that the tenants had a positive attitude towards the existing buildings and to the buildings' facades came as a surprise and will be a starting point for the final design of the renovation. Renovation processes as the studied can take many years to plan and execute and up till today the renovation of this larger estate is still not carried out. Once started the process is planned to go on for at least 10 years.

3. PRACTICAL AND MANAGERIAL IMPLICATIONS

The housing company have found the collaboration with the research team helpful especially the support to prepare the programme for the renovation but also the proposed business model for sustainable renovation. Based on the study, some practical recommendations were formulated by the research team:

1. Define economic frames and personal resources early to set the right ambition level.
2. Define long-term sustainable and holistic objectives. A renovation process can last for years, and the future of the area should be considered. Plan for the inclusion of new knowledge and technology that can appear during the process.
3. Structure the process and define milestones along the way. Set up a plan for steps in the renovation process that are part of an integrated overall plan.
4. Define roles and responsibilities.
5. Set up rules for collaboration and communication.
6. Document the process and make this information available for all participants.
7. Search for and use available knowledge and tools for sustainable renovation.
8. Define a sustainable business based on: stakeholder analysis; a balance between costumer values and sustainability objectives; cash flow analysis in the short and long term; identified outcomes of the renovation and their long-term values.
9. Engage the residents early on.
10. Prepare different possible alternatives for the renovation.

FURTHER READING

Three papers/reports, will be added after the peer review

REFERENCES

ÁSTMARSSON, B., JENSEN, P. A. & MASLESA, E. 2013. Sustainable renovation of residential buildings and the landlord/tenant dilemma. *Energy Policy,* 63**,** 355-362.

BAETEN, G., WESTIN, S., PULL, E. & MOLINA, I. 2017. Pressure and violence: Housing renovation and displacement in Sweden. *Environment and Planning A: Economy and Space,* 49**,** 631-651.

FEMENÍAS, P., MJÖRNELL, K. & THUVANDER, L. 2018. Rethinking deep renovation: The perspective of rental housing in Sweden. *Journal of Cleaner Production***,** In press.

GLUCH, P., GUSTAFSSON, M., BAUMANN, H. & LINDAHL, G. 2018. From tool-making to tool-using– and back: rationales for adoption and use of LCC. *International Journal of Strategic Property Management,* 22**,** 179-190.

MANGOLD, M., ÖSTERBRING, M., WALLBAUM, H., THUVANDER, L. & FEMENÍAS, P. 2016. Socio-economic impact of renovation and energy retrofitting of the Gothenburg building stock. *Energy and Buildings,* 123**,** 41–49.

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Robust and reliable sustainability assessment tool for building renovation strategies

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ABSTRACT

Selecting the best energy-efficiency measure for retrofitting existing buildings is difficult due to the uncertainties of events during the life span of the building. This project will propose a robust and reliable assessment of various renovation strategies for the building stock in Switzerland based on life cycle assessment and life cycle costing. Through statistical calculations for uncertainty propagation, the project will provide an insight on the uncertainties, which might occur during the life stage of the building. Different renovation packages will be defined. For each of them, the uncertainty of the relevant input parameters will be evaluated to identify the most robust solutions. Finally, the results will be used to provide guidelines on robust renovation strategies for Switzerland that can be used by architects, clients and policy makers.

Keywords: building renovation, life cycle assessment, life cycle cost, uncertainty quantification

1. INTRODUCTION

Buildings are one of the largest energy consumers and greenhouse gas emitters in the world (UNISTATS, 2010). As the biggest part of the energy consumed by the existing non-insulated building occurs during operation stage (Sartori and Hestnes, 2007), retrofitting the building stock is important to reduce the environmental impact. To evaluate total environmental impact from the material excavation through operation stage to the building demolition and recycling, it is important to assess the whole life cycle. Life cycle assessment (LCA) and life cycle costing (LCC) are common approaches for full building evaluation. Several studies proposing combined LCA and LCC for achieving the optimal renovation were performed (Almeida and Ferreira, 2015; Ott et al., 2017; Périsset et al., 2016). However, due to the long lifespan of a building, there are many uncertainties on which events might occur during life cycle of the building. The uncertainties associated with external or internal parameters can lead to deviations in the results that could be higher than the difference between deterministic values (Fawcett et al., 2012). Hence, to be able to propose a robust information regarding different renovation scenarios, uncertainty quantification and assessment are needed.

The objective of this project is to create a robust and reliable assessment of different renovation strategies for existing building stock of residential buildings in Switzerland. The proposed method includes the uncertainty sources identification related to LCC and LCA, uncertainty propagation of these sources and establishment of the sources with highest contribution to the results (so-called *sensitivity analysis* (Sudret, 2007)). The idea of the project is to demonstrate that simulations that take into account only most probable values are inefficient in a long term perspective due to uncertainties (See Figure 1). The goal is to develop a method to decrease the uncertainty through a rigorous statistical treatment and compare different renovation solutions for existing the building stock.

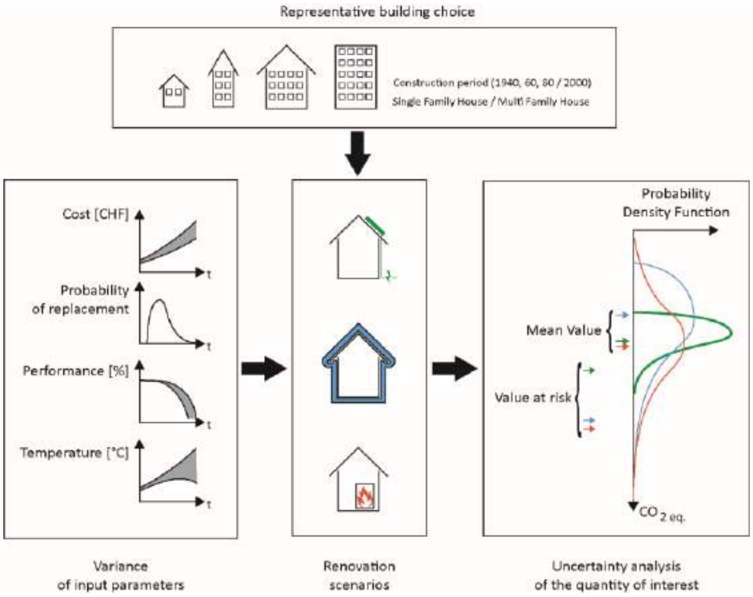

FIGURE 1 – SCHEMATIC DESCRIPTION OF THE PROJECT

2. METHOD

The focus of the project is on three quantities of interest (QoI) – LCA, LCC and thermal comfort. The analysis will be performed for the whole life cycle of the building and include uncertainties associated with future scenarios, *e.g.* external temperature, solar irradiation, financial parameters, material service life, nature of the energy carriers, etc. as well as uncertainties associated with the design: true dimensions of the real system, material properties and performance loss.

The project will be performed in several stages. The first and current stage is the computational model creation for all the QoI. The identification of the model parameters, which define the future scenarios, is essential for further uncertainty propagation. The heating demand will be calculated according to the Swiss standard for energy calculations (SIA 380, 2001). The overall environmental impact including the replacement stage will be analysed using LCA. In addition, the life cycle costs will be evaluated using the net present value (NPV) approach.

For the second stage, the identification of the parameters type and variation with statistical moments (*e.g.* mean and standard deviation) are needed in order to perform uncertainty propagation. *Polynomial chaos expansions* (PCE) will be used for uncertainty propagation and sensitivity analysis, because they are a reliable and comprehensive method for highly parameterized and complex models (Le Gratiet et al., 2017, Hover and

Triantafyllou, 2006). The advantage of PCE compared to other statistical approaches (for instance Monte Carlo simulation) is the low cost: the PCE is fitted from a set of runs of the complex simulator (called DOE, design of computer experiments), usually a few tens to a few hundreds; Once the PCE is built from this data, it is used as a surrogate model, which can then be evaluated millions of times at no cost.

Using the PC expression of the various quantities of interest, sensitivity analysis, which aims at quantifying which input parameters of the model influence the most the model outputs, can be carried out: sensitivity indices known as Sobol' indices (Saltelli et al., 2008) can be computed from the PCE coefficients analytically (Sudret, 2008). This will allow to simplify the overall modelling, *i.e.* to fix to deterministic best-estimate values all the parameters which do not influence the quantities of interest.

Uncertainty propagation also allows to determine the probability distribution functions of the quantities of interest as well as their statistical moments.

In parallel, the detailed characterization of the existing building stock in Switzerland will be performed with the focus on the construction period and the structural material. This will be done to identify the reference buildings, which will be representatives for the building stock. The building renovation packages for each of the building types will be determined with regards to the envelope renovation, heating system or energy production systems and various combinations of these measures.

3. CONCLUSION

The calculation of uncertainties is necessary to compare two renovation strategies due to the long life cycle of the buildings. This project proposes a method for the evaluation of building renovation strategies in terms of robustness and reliability. In the end of the project, the detailed assessment of the renovation packages will be achieved and the most relevant parameters with the highest effect on the model response will be identified. Finally, the results will be used to provide guidelines on robust renovation strategies for Switzerland that can be used by architects, clients and policy makers.

REFERENCES

Almeida, M., Ferreira, M., 2015. IEA EBC Annex56 Vision for Cost Effective Energy and Carbon Emissions Optimization in Building Renovation. Energy Procedia 78, 2409–2414. https://doi.org/10.1016/j.egypro.2015.11.206

Fawcett, W., Hughes, M., Krieg, H., Albrecht, S., Vennström, A., 2012. Flexible strategies for long-term sustainability under uncertainty. Building Research & Information 40, 545–557. https://doi.org/10.1080/09613218.2012.702565

Hover, F.S., Triantafyllou, M.S., 2006. Application of polynomial chaos in stability and control. Automatica 42, 789–795. https://doi.org/10.1016/j.automatica.2006.01.010

Le Gratiet, L., Marelli, S., Sudret, B., 2017. Metamodel-based sensitivity analysis: polynomial chaos expansions and Gaussian processes. Handbook of Uncertainty Quantification, Ghanem, R. Highdon, D. and Owhadi, H. (Eds.), Springer.

Ott, W., Bolliger, R., Ritter, V., Citherlet, S., Lasvaux, S., Favre, D., Périsset, B., de Almeida, M., Ferreira, M., Ferrari, S., 2017. Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56). University of Minho.

Périsset, B., Lasvaux, S., Hildbrand, C., 2016. Expanding Boundaries - Economic and Environmental Assessment of Building Renovation: Application to Residential Buildings Heated with Electricity in Switzerland – B. Périsset, S. Lasvaux, C. Hildbrand, D. Favre, S. Citherlet. https://doi.org/10.3218/3774-6_56

Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana,M., Tarantola, S., 2008. Global sensitivity analysis - The primer. Wiley

Sartori, I., Hestnes, A.G., 2007. Energy use in the life cycle of conventional and low-energy buildings: A review article. Energy and Buildings 39, 249–257. https://doi.org/10.1016/j.enbuild.2006.07.001
Sudret, B., 2007. Uncertainty propagation and sensitivity analysis in mechanical models - Contributions to structural reliability and stochastic spectral methods. Habilitation thesis, Université Blaise Pascal, Clermont-Ferrand, France
Sudret, B., 2008. Global sensitivity analysis using polynomial chaos expansions. Reliability Engineering & System Safety 93, 964–979. https://doi.org/10.1016/j.ress.2007.04.002
SIA 520 380/1, 2001. Thermische Energie im Hochbau, 56.
UNISTATS. (2010). Greenhouse gas emissions by sector (absolute values).

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Do we know how many buildings are actually renovated ? Estimation methods in a context of incomplete data.

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ABSTRACT

Many EU Member States set up policy actions to stimulate deep energy renovation. To monitor their effectiveness, knowledge of the actual renovation rate is indispensable. Since years, a renovation rate of ca.1% is assumed (and considered too low to be effective), but this neglects the many renovations executed without building permit. However, most of these renovations are very poorly documented in databases leading to a high uncertainty on the actual renovation rate. This paper presents two approaches for Belgium, to monitor the renovation activity, in a context of incomplete data and partly laymen information sources.

Keywords: renovation rate; databases; renovation activity; effectiveness of policy, barometer

1. INTRODUCTION

Like many other EU Member States, also Flanders, Belgium is stimulating deep energy renovation in order to improve the energy performance of the existing building stock substantially by 2050. In this context was the Renovation Pact established in 2014 (Renovatiepact, n.d.), as a follow up of the Energy Renovation Program of 2007, with specific long term goals for the overall energy performance level and minimal requirements for energy efficient measures. To be able to monitor the progress and effectiveness of the Renovation Pact, knowledge of the actual renovation rate is indispensable. Also for the construction sector this knowledge is necessary to prepare its business activities to the actual demand for renovation. Since years, a renovation rate of 0,7 to 1% is assumed and used as an argument that renovation should be stimulated, but this figure only represents renovations with building permit (ADSEI, 2017). It can be assumed that the actual renovation rate is larger, since many energy efficiency measures are executed without building permit. However databases on the existing building stock contain limited information on energy efficient measures and most renovations are very poorly documented in databases and thus remain under the radar. This paper presents two approaches that have been developed in a context of incomplete data and laymen information sources, to support the Flemish government and the construction industry in determining the actual renovation rate in order to assess the need for adjustments of the policy actions for energy renovation.

2. METHODOLOGY

The first approach has been set up by Essencia Marketing, a marketing agency specialized in the construction sector. It consists of two online surveys that are yearly executed since 2012 (Essencia-Marketing, 2017) . The first online survey questions a representative sample of Belgian households (n=1000) on their renovation activities: if they did a renovation activity in the past year and if so, which kind of renovation (e.g. wall insulation, roofing, electricity, kitchen, …). The second online survey only questions households (n=1000) who executed at least one renovation work in the past year. Aim is to collect more details about the renovation works (e.g. type and volumes of building materials used, applied techniques, executor, ..). The questionnaires were tested through in-depth-interviews with renovators (n=18) on understanding of the questions, ability to answer them and accuracy of the answers.

The second approach aimed at developing indicators to monitor yearly the effect of Flemish policy actions on policy goals, such as reduction of energy consumption and CO2 emissions, application of energy efficient measures and number of dwellings meeting the 2050 requirements (Verbeeck and Housmans, 2017). Therefore all available databases with information related to the performance of the existing building stock and renovation activities were analysed. The databases consist on the one hand of governmental, SILC and Eurostat statistical data on a.o. the energy balance of Flanders, energy labels of dwellings, subsidies for energy efficient measures, energy loans, cadastral characteristics of the building stock, surveys of households, building permits for new construction and renovation, household expenses and VAT-declarations. On the other hand data were collected from federations of contractors, producers of heating systems, notaries and the financial sector on construction and renovation activities, sales figures and mortgage and consumer loans. All databases were analysed for type of information, frequency of update, reliability, ease of access and employability for the indicators. Furthermore, approaches in other countries were studied (EPISCOPE, 2014).

3. RESULTS

3.1. Usefulness of online surveys among home owners

The results of the online surveys show that home owners are able to inform on the type of renovation works and that more detailed information on technical aspects is available in most cases in offers, invoices or subsidy application, but respondents need a stimulus to consult these documents. Also, some problems remain unsolved: 1) an underrepresentation of socially weaker households due to a lower use of the internet; 2) high uncertainty on the accuracy of responses on questions about the present situation, as homeowners tend to rely on what the former home owner told them, 3) little knowledge among consumers on used building materials and brands, especially when the renovation work is executed by a professional, while this information is crucial for the industry.

3.2 Usefulness of databases to develop a renovation barometer

The analysis of the databases and international literature showed that the current data are insufficient to develop accurate indicators on the current state of the energy performance of the building stock or on the renovation rate. This is not only the case for Flanders, but for all EU countries. In view of the need from policy makers and producers for a frequent tri-monthly follow-up of the renovation activities, quick availability of trend figures appeared to be more important than accuracy. Therefore a renovation barometer was developed that aggregated the evolution of granted subsidies for insulation and thermal glazing, sales of condensing boilers, mortgage loans for purchase + renovation, building permits for demolition and renovation and estimation of the work load by contractors.

3.3 Estimation of the renovation activity by the two approaches

The results of the online surveys show a delay of the renovation rate since 2013 (figure 1).

Except for 2016, the yearly percentage of renovators is declining (from 41% in 2012 to 34% in 2017). The surveys also show a declining interest in energy saving measures. The aggregated renovation barometer (figure 2) shows that the positive trend has stopped in 2016 with a strong decline since 2017. This tendency is also confirmed in discussions with the construction sector.

Figure 1: Renovation rate among Belgian home owners (in % of representative sample)

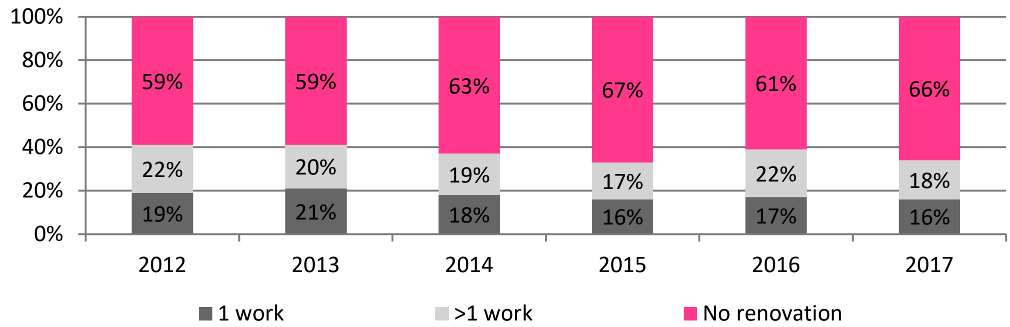
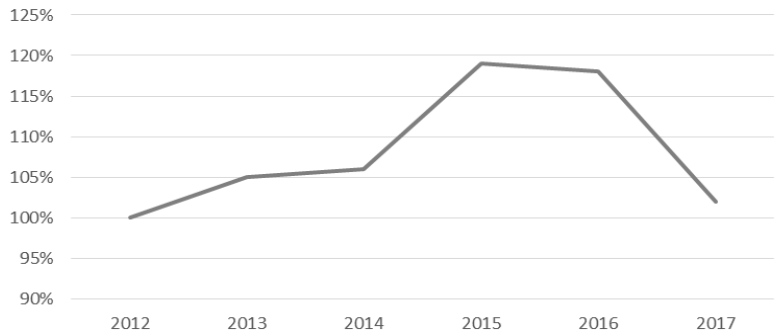


Figure 2: Aggregated renovation barometer (in % compared to 2012)



4. CONCLUSION

Although knowledge of the actual renovation activity is crucial to monitor the effectiveness of policy actions, up to now no country appears to have an accurate method to do so. The implementation of a building passport for each building with detailed information on its characteristics could be a solution, but only in the long term. In attendance, available databases can be used for a rough estimation of the renovation rate on a frequent basis (< 1 year). Online surveys, that give more accurate results, but are more labor- and cost-intensive, are then useful to cross-check and validate this evolution on a 1 to 5 year basis.

REFERENCES

ADSEI 2017. Statistics Belgium, http://statbel.fgov.be.

EPISCOPE Project Team 2014. Tracking of Energy Performance Indicators in Residential Building Stocks – Different Approaches and Common Results. Institut Wohnen und Umwelt, Germany.

ESSENCIA MARKETING, 2017. Analyse van de Belgische renovatiemarkt in 2017.

RENOVATIEPACT n.d. Bis-Conceptnota aan de Vlaamse Regering, betreft: Renovatiepact. Brussels.

VERBEECK, G. & HOUSMANS, K. 2017. Report VEA/REG/2016/LP/02 Renovatiebarometer Vlaanderen.

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Risk Framework on Housing Energy Retrofitting in China

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ABSTRACT

In China, the majority of existing residential buildings show poor energy performances due to the lack of energy conservation regulations before 2000. Moreover, the development of housing energy retrofitting in China is at a slow pace due to risks that are for instance related to unexpected payback periods and reliability issues. Other risks are caused by bounded rationality and opportunism, induce transaction costs, e.g., information searching cost, negotiation cost. This study aims to investigate the risks of housing energy retrofitting projects from planning to operation from a transaction costs perspective. The paper first reviews on generic risks and reveals the hidden risks by considering transaction costs that can occur during the construction and renovation process. Based on the generic risk review framework, in-depth interviews with the practitioners and government officials in China were held to adapt the risk framework based on Chinese renovation cases into Chinese context. This paper presents the main insights.

Keywords: Housing energy retrofitting; Risks; Transaction costs (TCs)

1. INTRODUCTION

In China, about 70% of the urban residential buildings are showing poor thermally conditions (Zhao et al., 2009). Unlike the industrialized countries with ambitious energy standards for buildings, China had few provisions on building energy efficiency before 2000, which also resulted in high energy consumption in existing residential buildings (Ouyang et al., 2011b). Nowadays, these existing residential buildings have been recognized as having a great potential for energy savings through energy efficiency renovation programs in China (Ouyang et al., 2011a).The Chinese government has made much effort to improve the energy efficiency performance of existing residential buildings. By the end of 2015, 990 million m^2 housing energy retrofitting projects were completed in the northern region and 70.9 million m^2 in the hot summer and cold winter (HSCW) zone, but this number is rather small compared to more than 20,000 million m^2 unban residential buildings with high energy consumption. On the whole, the development of housing energy retrofitting in China is still low, especially in hot summer and cold winter zone where housing energy retrofitting is still in the pilot stage.

Housing energy retrofitting projects in China are susceptible to many potential risks due to its particular Chinese context, examples would be, decentralized property rights, strong dependency on the government, and limited practical experience. There is a link between barriers to housing energy retrofitting promotion and risks affecting the smooth development of housing energy retrofitting. According to the barriers framework (Wilson et al., 2013), many barriers to housing energy retrofitting promotion are relevant to risks, like for instance a lack of external capital source, long pay-back period, unrealized energy savings and poor work quality. As a result, risk can be regarded as one of the main barriers to housing energy retrofitting promotion. It is necessary to analyse the risks in the implementation of projects to help smooth the process of housing energy retrofitting.

In general, risks analysis is conducted in order to evaluate the benefits of the retrofitting investment (Menassa, 2011, Gustafsson, 1998, Heo et al., 2012). Energy savings under uncertainties are often viewed as the basis for assessing the energy efficiency measures (Heo et al., 2012, Rysanek and Choudhary, 2013). In these studies, risks are associated with the value of energy efficiency measures and affect the actual energy savings. However, risks should not be only considered in the investment decision-making stage but also managed from the perspective of the life cycle. In reality, most risks are interrelated with different project stakeholders (Yang and Zou, 2014). In addition to the generic risks (e.g. technology, organization, finance) (Mills et al., 2006, Biekša et al., 2011), some hidden risks also exist in the transactions among these parties, such as opportunistic behaviours and moral hazard (Chauhan et al., 2017). According to transaction costs economics (TCE), the characteristics of transactions and the parties involved include asset specificity, uncertainty, bounded rationality and opportunism, which can be regarded as the main factors causing hidden risks. Therefore, this study aims to identify the risks affecting the smooth implementation of housing energy retrofitting in China with transaction costs (TCs) considerations.

2. RESEARCH METHODOLOGY

2.1. Literature review

According to the previous studies (Biekša et al., 2011, Caputo and Pasetti, 2015, Booth and Choudhary, 2013, Olgyay and Seruto, 2010, Ferreira and Almeida, 2015, Bao et al., 2012, Rovers, 2014, Mitropoulos and Howell, 2002, Fylan et al., 2016, Mills, 2003), 17 generic risks affecting the smooth development of housing energy retrofitting are identified. These generic risks can be divided into six categories, including politics and organization, technology, context, finance, on-site implementation and management, and operation. Furthermore, based on TCE (Williamson, 1975, Dorward, 2001, Parker and Hartley, 2003), this study explores eight hidden risks during housing energy retrofitting process in the Chinese context: imperfect information on the regional environment, uncertainty on property right and occupancy, uncertain technology effects, adverse selection, uncertainty on the on-site conditions, moral hazard, opportunistic renegotiation, and measurement problems. These risks are located in five phases of housing energy retrofitting projects and related to four stakeholder groups (namely government, contractors, designers and occupants).

2.2. Interview

Semi-structured interviews were conducted with 23 interviewees in China. Four of these interviewees, from provincial government, the government of provincial capital and research institution, were first interviewed to discuss the general situations of housing energy retrofitting and the common risks affecting the implementation. All the rest are directly involved in study cases in this study, representing different stakeholder groups in housing energy retrofits.

Three housing energy retrofitting projects were chosen as study cases. The three projects are located in Anhui province in the HSCW climatic zone, and were implemented and completed in 2017. Retrofitting technologies of the three projects are relatively comprehensive, including external thermal insulation, roof insulation and the replacement of windows. These are also the main retrofitting items mentioned in the technical guide of retrofitting projects in Anhui province.

Nineteen major participants in the above projects were invited to take part in the interviews, including 7 government officials, 4 designers, 4 construction managers, and 4 homeowners. As the representatives of different stakeholder groups in housing energy retrofitting projects, they have a good understanding of the work and responsibilities of their own group, and can elaborate on the problems they encountered and their concerns in the course of project implementation.

The interviews mainly focussed on four aspects: the work and tasks in the whole process of retrofitting projects; responsibilities and roles of the stakeholders; verification of the listed risks; stakeholders' concerns on these risks. After the interviews, the risk framework based on literature review for HER in China, including the original implementation process and the listed risks in each phase, were adjusted.

3. RESULT AND CONCLUSION

Based on literature review, this paper conducted the in-depth interviews with some main actors in three cases in China. According to the results of interviews, the risk framework for housing energy retrofitting projects, including the implementation process, stakeholders, and the corresponding risks, is adjusted to the Chinese context as shown below.

(1) Governmental financial budget and homeowners' approval are the premise of project implementation and are also the most common risks mentioned by almost all of interviewees.

(2) The measurement of the energy consumption before and after retrofitting is missing. This means that housing energy retrofitting projects in China have more exposure to uncertainties on design accuracy and construction quality.

(3) The risks related to the usage mode of occupants after retrofitting can be ignored in Chinese context due to the fact that less attention is paid to actual energy savings. At the same time various opinions and requirements of hundreds of households in a project lead to more risks with respect to the coordination and consensus among occupants and between occupants and the other stakeholders.

(4) Opportunistic behaviours are most likely to be caused by occupants and contractors due to the roles of occupants only as beneficiaries not investors and information asymmetry between contractors and the other stakeholder groups.

This paper has identified 21 risks in the whole process of housing energy retrofitting projects in China, which is the basis of further risk assessment. Also, a comprehensive understanding of risks can help develop more effective strategies for risk mitigation.

REFERENCES

BAO, L., ZHAO, J. & ZHU, N. 2012. Analysis and proposal of implementation effects of heat metering and energy efficiency retrofit of existing residential buildings in northern heating areas of China in "the 11th Five-Year Plan" period. *Energy Policy,* 45**,** 521-528.

BIEKŠA, D., ŠIUPŠINSKAS, G., MARTINAITIS, V. & JARAMINIENĖ, E. 2011. Energy efficiency challenges in multi-apartment building renovation in Lithuania. *Journal of civil engineering and management,* 17**,** 467-475.

BOOTH, A. & CHOUDHARY, R. 2013. Decision making under uncertainty in the retrofit analysis of the UK housing stock: Implications for the Green Deal. *Energy and Buildings,* 64**,** 292-308.

CAPUTO, P. & PASETTI, G. 2015. Overcoming the inertia of building energy retrofit at municipal level: The Italian challenge. *Sustainable Cities and Society,* 15**,** 120-134.

CHAUHAN, P., KUMAR, S. & SHARMA, R. K. 2017. Investigating the influence of opportunistic behaviour risk factors on offshore outsourcing. *International Journal of Business Excellence,* 12**,** 249-274.

DORWARD, A. 2001. The effects of transaction costs, power and risk on contractual arrangements: a conceptual framework for quantitative analysis. *Journal of Agricultural Economics,* 52**,** 59-73.

FERREIRA, M. & ALMEIDA, M. 2015. Benefits from energy related building renovation beyond costs, energy and emissions. *Energy Procedia,* 78**,** 2397-2402.

FYLAN, F., GLEW, D., SMITH, M., JOHNSTON, D., BROOKE-PEAT, M., MILES-SHENTON, D., FLETCHER, M., ALOISE-YOUNG, P. & GORSE, C. 2016. Reflections on retrofits: Overcoming barriers to energy efficiency among the fuel poor in the United Kingdom. *Energy Research & Social Science,* 21**,** 190-198.

GUSTAFSSON, S.-I. 1998. Sensitivity analysis of building energy retrofits. *Applied Energy,* 61**,** 13-23.

HEO, Y., CHOUDHARY, R. & AUGENBROE, G. 2012. Calibration of building energy models for retrofit analysis under uncertainty. *Energy and Buildings,* 47**,** 550-560.

MENASSA, C. C. 2011. Evaluating sustainable retrofits in existing buildings under uncertainty. *Energy and Buildings,* 43**,** 3576-3583.

MILLS, E. 2003. Risk transfer via energy-savings insurance. *Energy Policy,* 31**,** 273-281.

MILLS, E., KROMER, S., WEISS, G. & MATHEW, P. A. 2006. From volatility to value: analysing and managing financial and performance risk in energy savings projects. *Energy Policy,* 34**,** 188-199.

MITROPOULOS, P. & HOWELL, G. A. 2002. Renovation projects: Design process problems and improvement mechanisms. *Journal of Management in Engineering,* 18**,** 179-185.

OLGYAY, V. & SERUTO, C. 2010. Whole-building retrofits: A gateway to climate stabilization. *ASHRAE Transactions,* 116**,** 1-8.

OUYANG, J., LU, M., LI, B., WANG, C. & HOKAO, K. 2011a. Economic analysis of upgrading aging residential buildings in China based on dynamic energy consumption and energy price in a market economy. *Energy Policy,* 39**,** 4902-4910.

OUYANG, J., WANG, C., LI, H. & HOKAO, K. 2011b. A methodology for energy-efficient renovation of existing residential buildings in China and case study. *Energy and Buildings,* 43**,** 2203-2210.

PARKER, D. & HARTLEY, K. 2003. Transaction costs, relational contracting and public private partnerships: a case study of UK defence. *Journal of Purchasing and Supply Management,* 9**,** 97-108.

ROVERS, R. 2014. New energy retrofit concept:'renovation trains' for mass housing. *Building Research & Information,* 42**,** 757-767.

RYSANEK, A. & CHOUDHARY, R. 2013. Optimum building energy retrofits under technical and economic uncertainty. *Energy and Buildings,* 57**,** 324-337.

WILLIAMSON, O. E. 1975. Markets and hierarchies. *New York,* 2630.

WILSON, C., CRANE, L. & CHRYSSOCHOIDIS, G. 2013. Why do people decide to renovate their homes to improve energy efficiency. *Tyndall Centre for Climate Change Research, Norwich, UK, Working Paper*.

YANG, R. J. & ZOU, P. X. 2014. Stakeholder-associated risks and their interactions in complex green building projects: A social network model. *Building and Environment,* 73**,** 208-222.

ZHAO, J., ZHU, N. & WU, Y. 2009. Technology line and case analysis of heat metering and energy efficiency retrofit of existing residential buildings in Northern heating areas of China. *Energy policy,* 37**,** 2106-2112.

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The ComfortTool – Assessing perceived indoor environmental comfort improvements in four deep energy home renovations

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ABSTRACT

This paper discusses the use of the ComfortTool to check the hypothesis that deep energy renovations lead to higher perceived indoor environmental comfort in four recently renovated homes. The resident-centered tool has been developed in response to shortcomings of several tools that aim to promote and assess energy efficiency and lifelong living measures in home renovations. The study results suggest that although deep energy renovations do indeed result in higher perceived comfort, there is a point beyond which more efficiency measures do not increase comfort. The study also indicates that the ComfortTool is successful in both broadening and deepening the residents' awareness and understanding of the implemented renovation measures and their impact on comfort.

Keywords: Comfort; Energy Efficiency; Lifelong living

1. INTRODUCTION

In response to societal and policy goals on environmental and social sustainability, a significant number of labels and assessment systems have been researched that separately address energy efficiency and lifelong living (the latter refers to homes designed to fit residents throughout their life's stages) in housing. Some of these tools are also used in practice. However they are often created by and for scientists and building professionals thus requiring technical expertise to understand and operate. Examples are the *Zilveren Sluitel* by Inter in Belgium, *Lifetime Homes* in UK, The *RenovatieStarter* and *MijnBENovatie* tools by the Flemish government, the *EPB* energy calculation software, and the FP7-funded *Perfection* project which attempts holistic & quantified key performance indicators for buildings. These tools provide important information and produce relatively objective results but are usually too detailed and impractical for small projects like home renovations and are often focused on only energy efficiency or accessibility. To typical home owners considering renovation these tools are opaque, uninspiring, and more importantly they ignore the home owners' broader needs, desires and vision of the home which often spark the renovation works in the first place.

This paper discusses the use of the ComfortTool (CT) which is proposed in response to these shortcomings (Kapedani, Herssens, & Verbeeck, 2018). The tool is intended for raising awareness about both energy efficiency and lifelong living measures from a user perspective, and for improving communication between homeowners and building professionals on these topics. In particular, this study seeks to discern how the perceived level of indoor environmental comfort, as measured with the ComfortTool, is related to the implemented energy efficiency and lifelong living measures in a home renovation, and whether the ComfortTool raises awareness of these measures in the residents.

2. THEORETICAL BASIS

Previous research on a synergetic merging of energy efficiency and universal design fields through the concept of indoor environmental comfort (Kapedani, Herssens, & Verbeeck, 2016, 2017a, 2017b) has laid the foundations for further explorations on using comfort as a byway for increasing adoption of both.Since universal design is considered not an end but a strategy, we instead use the term lifelong living to indicate measures based on universal design thinking. Indoor environmental comfort is used to represent and promote a combination of energy efficiency and lifelong living measures in home renovations. Indoor environmental comfort in the ComfortTool includes aspects often addressed in energy-related indoor environmental quality studies as well as spatial & design related aspects.

As elaborated by (Kapedani et al., 2018) the tool rests on three interdisciplinary theoretical constructs: comfort at home as product rather than process; comfort as a relative rather than absolute value; and a person-environment fit dynamic. By treating comfort as a product we narrow this very broad concept to deal with just the physical aspects of the home that have an impact on comfort. The relative view of comfort (based on Kolcaba (1994)) implies that absolute measurement values do not make sense and that what we need to talk about is the change in perceived comfort due to an intervention, such as a renovation. By adapting the well-established Person-Environment Fit theory (see eg. Lawton and Nahemow (1973) or Su, Murdock, and Rounds (2015)) the ComfortTool is able to separate characteristics of the person and the environment and concentrating on the fit between the two. In practice this allows for a personalized analysis, a comfort profile, for each user and their home.

3. METHODOLOGY

The study pertains to four case study homes recently subjected to a deep renovation aiming to be nearly zero energy buildings. Two of these homes also aimed for a lifelong living design. The ComfortTool is used, within a semi-structured interview, to gauge residents' perceived levels of comfort before the renovation and after the renovation has been completed. The interviews were conducted during the winter months. Drawings and other documents are used to verify what measures have been actually implemented. The implemented measures and perceived comfort are then analysed side by side using expert judgement to reveal the links and discrepancies between the expected effects of the measures and the stated comfort improvements. The hypothesis is that deep energy renovations lead to higher perceived indoor environmental comfort.

4. RESULTS & IMPLICATIONS

The ComfortTool is demonstrated capable of capturing and representing the resident's feelings of comfort. As expected, deep energy renovation leads to significant overall improvement in perceived comfort. However, interestingly, the indicators of indoor environmental comfort most improved are much more varied than those directly addressed with energy efficiency measures such as temperature and air quality and instead include accessibility, noise, ease of maintenance and natural light among others. These non-energy improvements were also more prominent in discussions with residents who are not always aware of the actual measures implemented, but are quick to point out the comfort benefits. It underlines the importance of making a broader case for non-energy benefits of deep energy renovations.

However, the depth of renovation, i.e. the level of energy efficiency between the homes, did not seem to make much difference in the residents perception of comfort. In other words, there seems to be an optimum point beyond which more energy efficient measures do not provide more perceived comfort for residents. The interviews were conducted only in the winter, thus ignoring potential overheating issues in the summer. These results nonetheless suggest that further research is needed on the impact curve that energy efficiency measures have on comfort and how this can be improved with the inclusion of lifelong living measures.

There was a marked difference between the number of improvements mentioned by the residents versus those highlighted in their comfort profiles after using the ComfortTool. The tool in effect had made the homeowners realize and explicitly express a broader set of comfort benefits which they could then connect back to the renovation measures implemented. It enabled further questioning which allowed for a deeper and clearer understanding of how the residents' needs and desires had been addressed with the renovation. The residents also confirmed that the results from the ComfortTool are an accurate and understandable representation of how they feel about the comfort in their homes and how that has improved.

By making explicit the needs and desires of homeowners the ComfortTool can be used during the design process to improve communication between residents and building professionals, to raise awareness and widen the scope of renovation, and ultimately to hopefully influence decisions on the implementation of energy efficiency and lifelong living measures.

FURTHER READING

The ComfortTool is the result of PhD research on the merging of energy efficiency and universal design in home renovations to increase adoption of both. The online prototype of the ComfortTool can be accessed at www.comforttool.be (in Dutch).

REFERENCES

Kapedani, E., Herssens, J., & Verbeeck, G. (2016). *Energy Efficiency and Universal Design in Home Renovations–A Comparative Review.* Paper presented at the UD2016, York, UK.

Kapedani, E., Herssens, J., & Verbeeck, G. (2017a). Comfort in the Indoor Environment: A Theoretical Framework Linking Energy Efficiency and Universal Design. In G. Di Bucchianico & P. F. Kercher (Eds.), *Advances in Design for Inclusion: Proceedings of the AHFE 2017 International Conference on Design for Inclusion, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA* (pp. 303-313). Cham: Springer International Publishing.

Kapedani, E., Herssens, J., & Verbeeck, G. (2017b, September 2-5, 2017). *Integrating Energy Efficiency and Lifelong Living-Lessons from Practice.* Paper presented at the ENHR 2017, Tirana, Albania.

Kapedani, E., Herssens, J., & Verbeeck, G. (2018). *The ComfortTool – assessing and promoting energy efficiency and lifelong living measures in home renovations*. Paper presented at the DS2BE 2018, Brussels, Belgium.

Kolcaba, K. Y. (1994). A theory of holistic comfort for nursing. *Journal of advanced nursing, 19*(6), 1178-1184.

Lawton, M. P., & Nahemow, L. (1973). Ecology and the aging process.

Su, R., Murdock, C., & Rounds, J. (2015). Person-environment fit. *APA handbook of career intervention, 1*, 81-98.

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Evaluation of Circular Construction Scenarios in an Urban Context

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ABSTRACT

Abstract – "Circularity" is often mentioned as a paradigm by which resource consumption and related emissions could be radically decreased, but very few examples of circular city planning exist. For the municipality of Assen, three circular building scenarios were analyzed on their environmental and social-economic impact. Overall, 0.5 to 3.7 kton of CO_2 emissions could be avoided by applying circular building principles. Social and economic impacts of circular construction were noted in the form of job creation, knowledge development and increased value of dwellings. On the other hand, material costs increased in some circular scenarios due to the higher material demand for sake of more adaptable building design. The next step is the development of a pilot project.

Keywords: Circular economy; urban planning; sustainability assessment

1. INTRODUCTION

The rapid growth in the world population, especially in cities, leads to an increase in both resource demand as well as greenhouse gas emissions due to resource production. "Circularity" is often mentioned as a paradigm by which resource consumption and related emissions could be radically decreased, but very few examples of circular city planning exist. However, this does not mean that circular ambitions are non-existent in European cities.

The Dutch city of Assen is an example of a European city with circular ambitions. The city wants to become "more circular" in, amongst others, the construction sector. Several circular scenarios have already been developed: modular & adaptive new build dwellings, material reuse from former industrial area and deep retrofit of the inner city. Although these scenarios all include circular thinking, it is yet unknown how they compare to each other in terms of impact.

This study aims to quantify the impact of the three scenarios in the light of the three pillars of sustainability: people, planet and profit. The nature of the study is explorative and therefore semi-quantitative. With the results of this study, the city of Assen can decide what scenario they prefer and start building a test case in the form of a circular neighbourhood.

2. METHODOLOGY

The impact of the circular scenarios was estimated in comparison to the reference situation. The scenarios and reference situation were developed in close consultation with the municipality by means a workshop. The reference scenario entailed the construction of 100 dwellings on a new location ("currently grassland") and the alternative scenarios focused on flexible (i.e. adaptive) buildings, reuse of materials from an old industry area, and deep retrofit of abandoned buildings in the city centre. In each scenario, all other parameters were kept equal (see Figure 1). For the materialization of the scenarios, a general building material model was applied (Keijzer et al., 2017).

The scenarios were compared on their impact by using a mix of indicators reflecting all three pillars of sustainability. The selected indicators were: knowledge development and employment (job creation) for the people pillar, climate change and general environmental impacts expressed in shadow costs (SBK, 2014) for the planet pillar, and material costs and dwelling value for the profit pillar.

Several types of quick scan and expert judgement methodologies were used to estimate the impacts of the scenarios. These methodologies were developed in the IMPACT framework (Verstraeten-Jochemsen et al., 2017). These methodologies are based on quantitative calculations, but since the input of these calculations consists of expert judgements, general assumptions and estimations, the results are not as exact as they might seem and therefore they will not be presented quantitatively but only in a five point scale (++/+/0/-/--). The scale reflects the change in comparison to the reference situation.

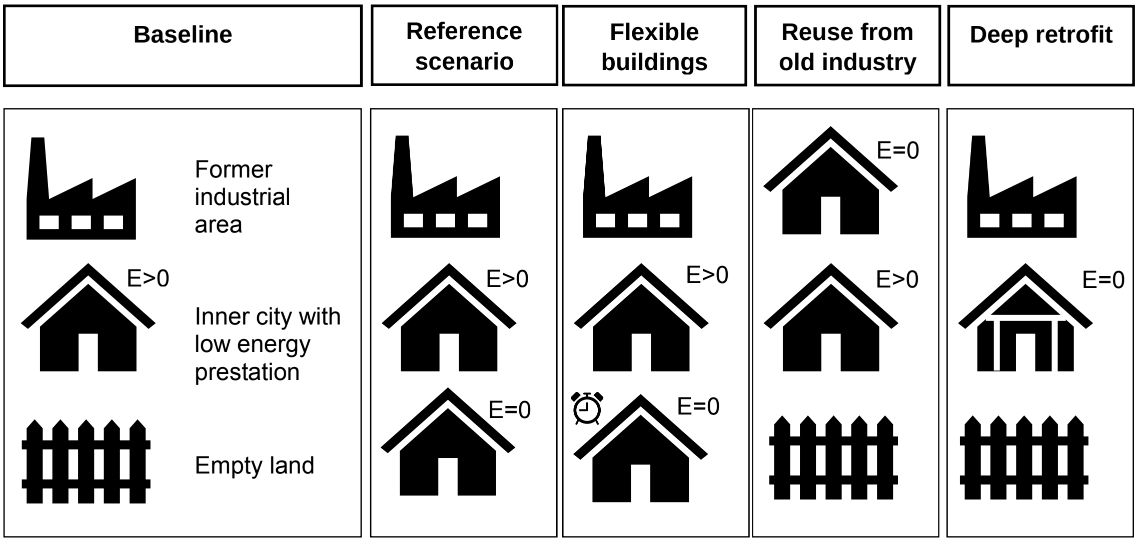

FIGURE 1. DESCRIPTION OF THE REFERENCE SCENARIOS AND THE THREE CIRCULAR SCENARIOS. IN ALL SCENARIOS, INCLUDING THE REFERENCE SCENARIO, 100 DWELLINGS ARE CREATED.

3. RESULTS

The three scenarios show different results in comparison to the reference scenario (see Table 1). In general, all scenarios score better than the reference scenario for knowledge development and all reflect approximately equal value of dwellings.

Large differences are seen for climate and environmental impacts, especially in the third scenario: deep retrofit of the inner city without energy measures creates much higher environmental impacts than the reference scenario, while the same scenario including energy measures creates a significant environmental improvement. The other two scenarios score also better on climate and environmental impact than the reference, where the second scenario (material reuse from former industrial area) scores somewhat better than the first (modular & adaptive new build). Overall, it was calculated that these scenarios could save 0.5 to 3.5 kton of CO_2 emissions and 120,000 to 700,000 euros of environmental impacts (shadow costs).

From a material cost perspective, only the second scenario and the third scenario without the energy measures are cost-neutral, while in the other scenarios the costs increase. Not shown in the table, is the result of the employability analysis, because the outcomes were hard to quantify. However, it is expected that all scenarios do increase local employability due to the knowledge development which is necessary for the circular transition. Nevertheless, the realized employment increase depends on, amongst others, the transition pathway and whether local knowledge partners will be included or not.

TABLE 1. RESULTS OF THE FOUR SCENARIOS IN COMPARISON TO THE REFERENCE SCENARIO.

Impact	**Scenarios**			
	Modular & adaptive new build	**Material reuse from former industrial area**	**Deep retrofit of inner city (with energy measures)**	**Deep retrofit of inner city (without energy measures)**
Climate change (CO_2 eq.)	+	+	++	- -
Environment (shadow costs)	0	+	++	- -
Material costs (€)	-	0	-	0
Knowledge development	++	++	++	++
Value of dwellings (€)	0	0	+	0

4. DISCUSSION AND CONCLUSION

The scenarios showed that the city of Assen can follow several pathways for circular construction projects and indicated the benefits and drawbacks of certain scenarios. In general, it can be concluded that both the implementation of energy saving measures and the reuse of local resources (preferably whole elements) lead to the highest gains, as measured by sustainability indicators. Adaptive and modular construction showed the lowest sustainability potential.

The study resulted in practical advises for the city of Assen on how to move on with their circular ambitions. The next ambition is to bring the ambition of one circular neighbourhood to practice in an European Horizon 2020 project. The researchers and municipality have, together with other parties, submitted a proposal which is now waiting for the second stage of evaluation.

FURTHER READING

Leeuwen, S., Kuindersma, P., Egter van Wissekerke, N., Bastein, T., Vos, S. de, Donkervoort, R., Keijzer, E. & Verstraeten, J. (2018). Circular building put into persepctive (in Dutch: Circulair Bouwen in Perspectief). TNO. Retrieved from: https://time.tno.nl/nl/artikelen/wat-levert-circulair-bouwen-op.

Vos, S.E. de, Keijzer, E., Mulder, G., Bonte, H. & Bastein T. (2017). Exploration of environmental impacts of circular construction of dwellings and utility buildings in The Netherlands (in Dutch: Een verkenning van de milieu-impact van circulair bouwen in de woning- en utiliteitsbouw). TNO report 10402 v2.

Bastein, T., Rietveld, E. & Keijzer, E. (2017). Ex-ante evaluation of the National Programme Circular Economy (in Dutch: Ex-ante evaluatie van het Rijksbrede Programma Circulaire Economie). TNO Report 10165.

Rietveld, E., Boonman, H., Chahim, M., Bastein, T. & Hu, J. (2018). Evaluation of the CO2 impacts of the national transition agendas for circular economy (in Dutch: Effecten van het Rijksbrede Programma Circulaire Economie en de Transitieagenda's op de emissie van broeikasgassen). TNO.

REFERENCES

Keijzer, E., Verstraeten-Jochemsen, J., Yu, V., Leeuwen, S. van, Visschedijk A. and Vos-Effting, S. de (2017). Bottom-up policy support: using a construction materials model to identify and quick scan circular opportunities. *HISER Conference Proceedings*, *pp 221-225.*

SBK 2014. *Assessment Method. Environmental Performance Construction and Civil Engineering Works (GWW).* Version 2.0, definitive, November 2014. Rijswijk: SBK.

Verstraeten-Jochemsen, J., Keijzer, E., Harmelen, T. van, Kootstra, L., Kuindersma, P. and Koch, R. (2018). IMPACT: a tool for R&D management of circular economy innovations. *Procedia CIRP, 69, pp 769-774.*

Local Roadmaps Encourage Zero-Carbon Social Housing

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ABSTRACT

Abstract - A broad assembly of parties has recently developed an approach that supports social housing associations, municipalities and tenants in the Netherlands in their joint effort to make their housing stock more sustainable. The approach for "Local Roadmaps towards Zero-Carbon Housing" and the related webtool offers participants insight in the scale, impacts and practical results for specific scenarios up to 2050. Based on representative cost and performance data for renovation measures, adapted to the local situation, the Local Roadmap tool supports the discussion between the three stakeholders and gives them the confidence to take action.
In the presentation we will we describe the design of the tool and discuss practical results achieved with it.

Keywords: Roadmaps; zero carbon; social housing

1. A GREAT NEED FOR INSIGHT IN SCENARIOS FOR SUSTAINABLE HOUSING IMPROVEMENT

Every responsible real estate owner or manager should nowadays ask him- or herself if and how the sustainable improvement of his building stock can be achieved. Due to international agreements, like the Paris climate agreement and derived national policy targets, there is an strong pressure from society to realize a zero-carbon built environment by 2050. The challenge is unprecedented in its scale and complexity, for some even threateningly complex. Therefore a great need exists for insight, overview and support in this operation. Where to undertake which efforts, at which point in time and at what costs? How to achieve sufficient pace, upscaling and capacity? And last but not least: how to obtain the required support among building users, authorities and sufficient decision power within the own organisation.

Below we will discuss in which context the Local Roadmap tool has been developed, what is its objective and how the tool and the related approach has led to real results in practical situations.

2. THE 'LOCAL ROADMAP TOWARDS ZERO-CARBO HOUSING'

Think global, act local! Since 2015, when the new legislation on social housing entered into force in the Netherlands, municipalities, social housing associations and tenants have been given more joint responsibility to establish agreements on local housing policy. Moreover, sustainability has become an obligatory aspect of the yearly performance agreements that are drawn up between these parties.

Roadmaps towards a zero carbon (social) housing stock depend strongly on the specific local situation and the efforts of involved parties. What is the present quality of the building stock? What are the policy plans with regard to the building portfolio? Has a regional energy and climate strategy already been formulated? Which approach is commonly used when executing technical interventions in the buildings? What does this mean for our daily practice, for our dwellings and homes and for our investments and energy bills?

Against this background W/E Consultants Sustainable Building has developed in a joint effort with representatives from the social housing associations (AEDES), the national tenants organisation (Woonbond) and in commission by the Ministry of the Interior and Kingdom Relations (Min. BZK) a new tool and approach which we call the “Local Road Map towards Zero-Carbon Housing”.

3.1. What is the Local Roadmap towards Zero-Carbon Housing?

A roadmap is an instrument that provides insight and overview in the routes that you can follow to arrive at the desired final destination. When considering the final destination in our context, a zero-carbon housing stock in 2050, this means that one can implement various technical measures within your housing stock at different points in time, which reduce or avoid CO_2 emissions. Examples of technical measures are:

- Demolishment, sale and new construction of dwellings;
- Improved insulation of roofs, façades, floors and windows;
- More efficient HVAC installations;
- Local generation of renewable energy;
- Connection to or “greening” of (local) networks for heat and/or electricity supply.

The ‘Local Road Map toward Zero Carbon Housing’ enables users to analyse various stepwise transformation scenarios for their own specific housing stock, policy objectives and local situation, taking into account the effects of technical interventions as mentioned above. Hereby the user obtains insight in the performance for parts or the entirety of the building portfolio, in terms of:

- CO_2 reductions as result of technical interventions in the building;
- Avoided CO_2 emission by means of renewable energy generation;
- Point in time when the zero carbon target is achieved;
- Required investment costs for each year;
- Effects on the Energy Performance of dwellings;
- Effects on energy costs for an average dwelling.

3.2. How does the ‘Local Roadmap towards Zero-Carbon Housing’ work?

The Roadmap tool utilizes available, verified data on the existing housing stock as the starting point for calculations. A distinction is made between dwelling types, amounts, size and expected exploitation strategy for clusters of dwellings. These data are complemented with the present energetic characteristics, both with regard to the building envelope and the installations. Subsequently, one can specify for each cluster certain technical interventions and related investments at maximally three points in time, up to the year 2050. The roadmap tool then immediately calculates the annual and cumulative CO_2 emissions as well as the financial costs and benefits.

By modification of assumptions and parameters the user can build scenarios which differ with respect to insulation values, installation components and performances, investment levels, energy prices and the CO_2 emission factor for the national electricity supply system. Also, the user can apply corrections for the actual energy consumption of a household in comparison with the standardized energy consumption as calculated on the basis of energy performance methodology[i]. Both building related energy consumption and total household energy consumption can be displayed.

By means of compact and easily understandable graphs and tables the results for specific scenarios can be viewed over the years, between the present date and 2050, as shown in the example graph below.

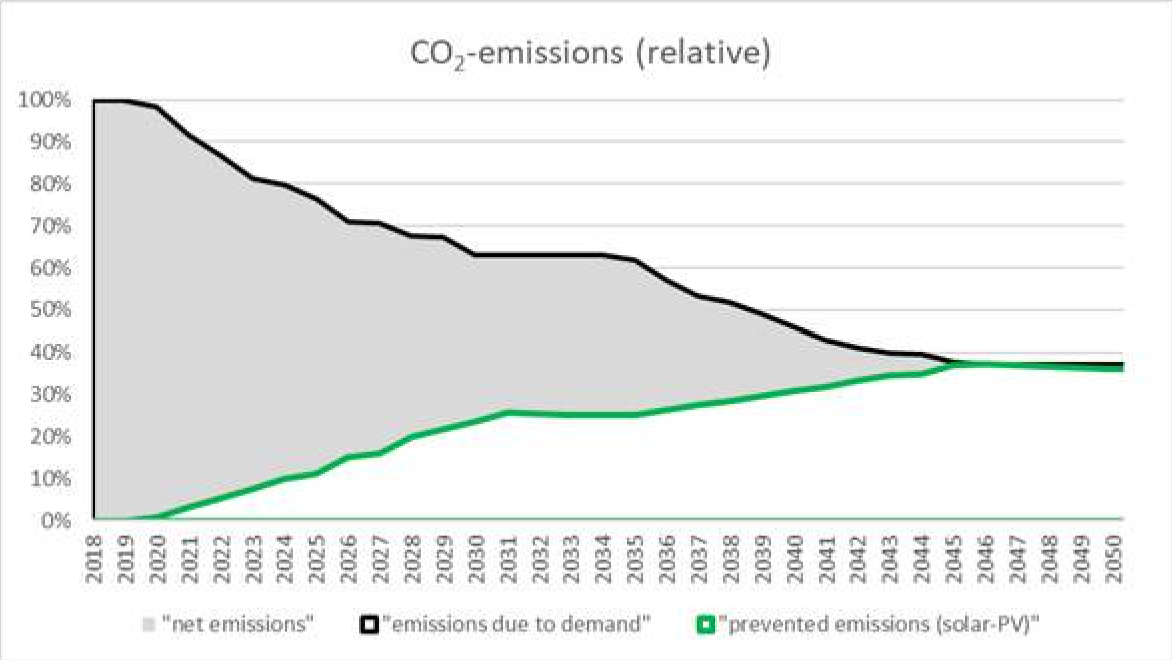

FIGURE 1: EXAMPLE GRAPH DEPICTING CO2 EMISSIONS FOR HOUSING STOCK, ASSUMING CERTAIN IMPROVEMENTS IN THE BUILDINGS AND AVOIDED EMISSIONS FROM SOLAR -PV INSTALLATIONS. IN THIS SITUATION THE ZERO-CARBON SITUATION FOR THIS HOUSING STOCK IS REACHED AROUND THE YEAR 2045.

3. FIRST EXPERIENCES FROM PRACTICE

Already during the development phase the Roadmap tool was evaluated and tested by local users in two municipalities. By now (June 2018) several dozens of roadmaps have been constructed for a good number of housing associations, together with municipalities and local tenant organisations. What have we learned from these practical exercises?

- The ‘Local Roadmap towards zero-carbon housing’ addresses the growing need from real estate owners and managers to come to terms with the required sustainability transformation of their real estate;
- The availability of energy label data, policy plans and validated cost and performance data allows users to make a quick start and realize short processing time with the tool;
- Input for initial key parameters and a stepwise refinement method are well in line with the existing primary processes within social housing organisations;
- The rates of demolishment, sale and new construction of dwellings, next to the possibility for connecting to a heat supply network, have an important impact on the emission reductions to be achieved within a building stock;
- With regard to the technical interventions in the persistent part of the housing stock, the preferred route is usually to firstly reduce the heat demand (in a pragmatic way)

and subsequently or concurrently install solar PV-systems where opportunities exist or occur. At a later point in time, at natural moments in the building maintenance plan, the heat supply installations may be replaced by more sustainable technologies, like electrical heat pumps;
- The stepwise approach which the Roadmap tool supports, shows opportunities for economically attractive alternatives for the costly 'Zero-on-the-Meter' renovations, where all measures are implemented at high level in one single renovation. Instead of performing such 'deep renovations' for a relatively small number of dwellings, a strategy of gradual improvement over a broad front also seems wise. The latter approach also reduces the financial and social risks from implementing untested technical innovations at larger volumes of buildings;
- The compact visual display of scenarios allows for communication with all relevant stakeholders (including tenants organisations) in a comprehensible manner, thus supporting the joint preparation of local performance agreements;
- The Roadmap approach helps to take away barriers in the thinking about the sustainable renovation challenge and offers the necessary confidence to continue on the present route or to become active in a pragmatic way.

Thanks to the positive experience and reactions to the 'Local Roadmap towards zero-carbon housing' by users and stakeholders, a publicly avaliable web-based version of the tool will be released in the course of 2018.

FURTHER READING

- www.aedes.nl/dossiers/energie-en-duurzaamheid.html#item-0
- www.woonbond.nl/nieuws/routekaart-co2-neutraal-gelanceerd

REFERENCES

[i] Majcen, D. and Itard, L. (2014) *Relatie tussen energielabel, werkelijk energiegebruik en CO2-uitstoot van Amsterdamse corporatiewoningen.* 1st ed. [pdf] Delft: OTB Technische universiteit Delft. Available at: http://www.otb.tudelft.nl/fileadmin/Faculteit/BK/Over_de_faculteit/Afdelingen/OTB/publicaties/Rapporten/2014_OTB-TU-Delft-Relatie-tussen-energielabel-en-werkelijk-energiegebruik.pdf [Accessed 9th may 2018]

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Developing Prefabricated Retrofit Solutions for the Housing Stock in Estonia

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ABSTRACT

The new Energy Performance of Buildings Directive (EPBD) aims at decarbonising the national building stocks by 2050. Achieving this goal means increasing the renovation volumes by factor 3. In Estonia, the renovation rate limit seems to be around 1% per year and rapid expansion of renovation volumes is not possible with current renovation technologies. More automated technologies are needed and prefabrication is one possible solution for the mass retrofit. Use of prefabricated wall insulation panels can reduce the time on site used for insulating external walls from current 2-3 months to 2-3 weeks.

Keywords: prefabrication, retrofit, apartment buildings

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1. INTRODUCTION

The new, revised Energy Performance of Buildings Directive (EPBD) aims to accelerate the cost-effective renovation of existing buildings and states that EU countries will have to establish stronger long-term renovation strategies, aiming at decarbonising the national building stocks by 2050 (European Commission, 2018). Achieving this goal means implying an average 3% renovation rate. Current renovation rate is approximately 1% per year (Artola, I., et al, 2016). Increasing the renovation volumes by factor 3 would require rapid expansion of the whole construction sector (designers, contactors, material industry), which may not be possible with current labour intensive renovation technologies. New concept for mass retrofit is needed in order to achieve decarbonised building stock by 2050.

2. RETROFIT OF EXISTING APARTMENT BUILDINGS

As other Eastern-European countries, a significant share of the housing stock in Estonia was built during the Soviet time industrialization construction period 1970-1990. Most of existing apartments buildings have been in use 30 to 40 years without retrofit and are in need for deep renovation. In total there are ~ 20 000 building and only approximately 1000 buildings have been renovated to meet major renovation energy efficiency level. Current renovation rate of apartment buildings in Estonia is approximately 1% (~200 buildings) per year. Demand is actually higher but increased renovation volumes created a new barrier in Estonia. Lack of funds and lack of awareness is often considered to be the main barrier for the renovation. In Estonia, the funds and awareness were not a main problems during the last couple of years. It turned out that when people actually start renovating their homes construction industry is not capable to handle the increased demand. Demand exceeded supply. Higher demand and limited number of construction workers increases the cost of retrofit.

3. PREFABRICATED RETROFIT SOLUTIONS

A pilot nZEB renovation with the use of prefabricated modular panels for building envelope insulation was conducted in Estonia. This is one of the first deep energy renovations that has been designed to correspond to the nZEB target of new buildings. The building type studied is a 5-storey apartment building used as dormitory (Figure 1).

FIGURE 1. PHOTO OF THE PILOT BUILDING BEFORE (LEFT), DURING (MIDDLE) AND AFTER (RIGHT) THE RENOVATION.

The building envelope above ground is insulated with prefabricated modular panels. Prefabricated modular panels consist of a timber frame structure filled with mineral wool. The total thickness of the thermal insulation in wall panels is 305-345mm: 30mm wind barrier, 70+195mm insulation between timber frames and 10-50mm light elastic mineral wool to fill the unevenness and roughness of the existing surfaces, U_{wall}=0.11W/(m^2·K). The total thickness of the thermal insulation in the roof modules is 340mm, U_{roof}=0.10W/(m^2·K).

Current main solution for the external wall insulation in renovation projects are external thermal insulation composite system (ETICS) and ventilated façade. ETIC system is preferred by the apartment associations because of the lower investment cost (~ 70 €/ wall m^2). Ventilated façade has slightly higher investment cost (~ 100 €/ wall m^2). Cost of the prefabricated wooden elements should be in the same range as the ventilated façade system with the similar constructional principles, in order to become widely used renovation solution.

FIGURE 2. EXTERNAL WALL INSULATION SYSTEMS: ETICS (LEFT), VENTILATED FAÇADE (MIDDLE) AND PREFABRICATED WOODEN INSULATION PANEL (RIGHT).

Cost of the pilot building prefabricated wooden insulation panel was ~180 €/ wall m^2 including installation and taxes. The pilot building was renovated to meet the nZEB (EPC class A) energy efficiency level. For renovation, EPC class A is not a cost-optimal solution. Current cost-optimal level for renovation is EPC class C (Arumägi, E., et al. 2017).

For renovation market aiming the EPC class C renovation, the thermal transmittance of the prefabricated modular panel can be higher than it was for the pilot renovation aiming nZEB level. Suitable solution would be for example 30mm wind barrier, 145mm insulation between timber frames and 10-50mm light elastic mineral wool to fill the unevenness and roughness of the existing surfaces, U_{wall}=0.15W/(m^2·K). Simpler and lighter prefabricated insulation panel would be more affordable and benefits of the prefabrication such as quality, durability and shorter renovation time would have an effect when home owners choose the renovation solution. For country level perspective, the installation speed would allow to increase the renovation volumes. Estimations are that insulating external walls with prefabricated panels would take approximately 2-3 weeks compared to the 2-3 months with current technologies.

Main barrier for the wider use of prefabrication for housing stock renovation is the cost. Even with the simpler wall insulation panel for the renovation market, the cost is ~150 €/ wall m^2 including installation and taxes (Ojarand, M.L 2018). Cost of ETICS system is approximately two times lower and although people would understand the benefits of the prefabricated elements, the limited budget for renovation sets restrictions for the technical solutions that can be used. Current estimations shows that possibilities to significantly lower the production cost with simplifying the prefabricated elements are limited. Cost problem may be relieved by future cost reductions due to economies of scale and larger production volumes.

4. CONCLUSION

Most of the housing stock in Estonia is not refurbished and suitable for the prefabricated modular panel renovation solution. Research and development work is ongoing in order to develop the product for the renovation market and decrease the production and installation cost. Renovation market is cost sensitive but with the affordable product for the renovation, there would be considerable market demand for the retrofit with prefabricated elements. It is not possible to handle the increased renovation volumes with current labour intensive and time consuming renovation technologies. More automated technologies are needed for the next step to decarbonise existing building stock.

FURTHER READING

Pihelo, P.; Kalamees, T.; Kuusk, K. (2017). nZEB Renovation of Multi-Storey Building with Prefabricated Modular Panels. *doi.org/10.1088/1757-899X/251/1/012056*

Pihelo, P.; Kalamees, T.; Kuusk, K. (2017). nZEB Renovation with Prefabricated Modular Panels. *doi.org/10.1016/j.egypro.2017.09.708*

REFERENCES

Artola, I., Rademaekers, K., Williams, R., Yearwood, J. 2016. Boosting Building Renovation: What potential and value for Europe?
Arumägi, E., Simson, R., Kuusk, K., Kalamees, T., Kurnitski, J. 2017. Hoonete kuluoptimaalsete energiatõhususe miinimumtasemete analüüs. (in Estonian)
European Commission Website, 2018. https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
Ojarand, M.L. 2018. The analysis and development of prefabricated reconstruction elements (in Estonian)

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Prefabricated modules for deep energy retrofitting of post-war multifamily residential buildings in Czechia

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ABSTRACT

The paper presents development and testing of a system of prefabricated modules based on wood frames and thermal insulation that were designed for deep energy retrofitting of post-war multifamily residential buildings in central Europe, especially in Czechia. The modules integrate new HVAC systems and sensors in order to control and improve the quality of the indoor environment.

Keywords: deep retrofitting; residential buildings; prefabrication

1. INTRODUCTION

The EU aims at the goal of erecting only near-to-zero operation energy level buildings after 2020; according to further-going Roadmap for moving to a competitive low carbon economy in 2050 (European Commission, 2011), the European Council also sets the goal of 80 to 95% cuts in emissions by 2050. The building sector is one of the main energy consumers and emission polluters; about 40% of overall EU energy consumption together with about 35% of overall CO_2 emissions release is attributed to buildings (Directive 2010/31/EU). The construction industry is pushed tough for the highest possible energy and emission cuts. At least 3% of renovations yearly must comply with the low energy level to reach the EU's energy targets.

1.1. Objective

The purpose of the paper is to present a concept for a modular deep energy retrofitting of Czech post-war multifamily residential buildings.

2. BACKGROUND

2.1. Housing typology

Based on statistic research, the most frequent multi-family residential building in Czechia is a 3-story building built in the period from 1946 to 1960. Such typology covers about 5% of the complete Czech multifamily housing stock. As a reference building was chosen post-war residential block in Milevsko, which by its typology and material basis represents a significant part of the residential housing stock of Czechia due for retrofitting.

This particular building, used as social housing, has 24 studios (room, kitchen, bathroom, hall), 31 m2 each, in three stories (see Figure 1). Technical or housing facilities and cellars were put in the basement, which is partially under the ground. Entrance to the building is on the northern façade, leading to the wide central hall with north-south orientation. At the southern façade, central hall is ended with a loggia. Each flat has two windows oriented either to the east or to the west. The building has a gable roof (33°), attic space is currently unused. Building has longitudinal wall structural system made of bricks (450 mm), ceilings are made of reinforced concrete. Façades are plastered, windows and exterior doors are partly original, partly (3 of 24 studios) replaced with insulating double-glazing, both with wooden frame.

FIGURE 1. *TYPICAL REPRESENTATIVE OF THE HOUSING TYPOLOGY IN QUESTION IN CZECHIA*

In the time the reference building was build, usual U-values varied (there were no standards then): 0.76–1.72 W/(m2K) for the roof, 1.07–1.70 W/(m2K) for the wall, 0.76–1.22 W/(m2K) for floor and 2.18–3.44 W/(m2K) for windows and doors. The total heat loss of the building is 2,037 W/K from which ventilation is responsible for 12 % and remaining 88 % is accounted to heat flow by transmission. The annual energy consumed by one reference building is around 1050 GJ.

3. RETROFITTING STRATEGY AND TECHNICAL CONCEPT

2.1. Retrofitting strategy

The general strategy came out from the analysis of the typical representatives of the select typology, their technical shape and needs, and from the SWOT analysis of typical common retrofitting interventions that are offered on the market nowadays.

The limitations given by the building typology are given by the fact that the major part of the building envelope is at the same moment the load bearing structure – typically the masonry walls of 450–600 mm form the supporting structure for the concrete floor structures. Therefore, there is no option for replacements, the only way is to make an addition upon the existing walls. There is planned an additional layer of thermal insulation to be placed in the attic and the floor above the cellar will be insulated as well. A mechanical ventilation system with heat recovery provides space heating and supplies fresh air into each of living rooms. The air ducts are integrated in the wall panels together with sensors for controlling the indoor environment in each apartment.

2.1. Technical concept

The technical concept is presented in the following Figures 2-3.

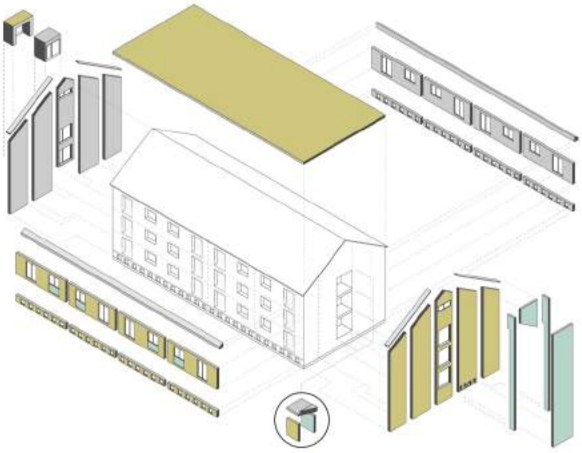

FIGURE 2. *THE CONSTRUCTION MODULES FOR DEEP ENERGY RETROFITTING.*

FIGURE 3. *VISUALISATION OF ONE WALL MODULE WITH INTEGRATED AIR DUCTS AND HEATING SYSTEM.*

The modules were prototyped and their functionality was validated in a pilot installation at a mock-up house that simulated the critical details of a typical multifamily residential building.

ACKNOWLEDGEMENT

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REFERENCES

- European Commission. 2011. A Roadmap for Moving to a Competitive Low Carbon Economy in 2050.
- Directive 2010/31/EU of the European parliament and of the council of 19 May 2010 on the energy performance of buildings

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Carbon Neutral Retrofits in Cold Climates: Lessons from New England

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ABSTRACT

Abstract: Cold climates present a series of thermal challenges for carbon neutral retrofits. In operation-oriented neutrality however, where only HVAC (heating ventilation and air conditioning), lighting and mechanical systems related emissions are considered, there are relatively simple thermal solutions such as high performance insulation and/or onsite power generation solutions such as photovoltaic panels. These challenges are substantially intensified when embodied emissions are considered in addition to operating emissions. The added complexity is due to the significant carbon footprint of the production of high performance materials and energy harvesting devices. Within this context, this paper discusses the design, analysis, and construction of a life-cycle carbon neutral retrofit of a 1920's house in Cambridge, Massachusetts.

Keywords: Carbon neutral retrofits; Embodied energy; Life cycle assessment

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1. INTRODUCTION

Carbon neutral design has emerged in recent years as a widely adopted alternative to meeting environmental rating system requirements such as LEED. While aiming at reducing direct environmental impact is a positive trend, many carbon neutral retrofit projects tend to concentrate solely on offsetting operation-related emissions [1]. In such projects, fossil-based energy sources for day-to-day operation of HVAC and mechanical and lighting systems are substituted with renewable sources. In many cases, this effort results in the addition of photovoltaic panels, wind turbines, geothermal systems or other forms of onsite power generation to buildings or infrastructure. These features unquestionably work to reduce direct emissions from energy consumption and add a visual layer to the buildings they are applied to. However more often than not, manufacturing energy harvesting and storage devices such as PVs and batteries involve energy-intensive production processes. At a system-wide perspective therefore, some devices just transfer emissions from site to production facility rather than reducing impact altogether. This situation is exacerbated in cold climates, where there is often an increased demand for heating and less availability of solar power. Frequently, the solutions provided for low energy retrofits in these climatic zones include installation of higher performance insulation materials [2] and reliance on wind and geothermal energy – which in turn might increase the overall carbon footprint of the retrofit rather than reduce it. With these challenges in mind, this paper describes the refurbishment of a 1920's timber frame single family house in Cambridge, Massachusetts. The project, which also included the conversion of the house into an academic research facility, targeted full carbon neutrality by offsetting both operating-related and embodied emissions. The purpose of the paper is to discuss the methodology and key challenges in the design of the retrofit in order to inform practitioners and facilitate similar carbon neutral retrofits in cold climates in Europe.

FIGURE 1. THE BUILDING PRIOR TO THE RETROFIT.

2. METHODOLOGY

A key component in the design and subsequent construction of this retrofit project was an analysis of both the operating load of the various systems in the building and the carbon footprint of the materials that were to be used in the retrofit. The former objective was achieved through the construction of a series of simulation models that were meant to predict energy consumption, availability of natural ventilation, and artificial lighting loads. The latter objective was achieved through a combination of building information modelling (BIM) and life cycle assessment tools. A building information model is a 3D computational model that stores material data regarding each component in the building. Life cycle assessment tools enable the calculation of carbon footprint of products and processes, taking into consideration the sourcing, processing, production, delivery and assembly of building materials. The combination of these methods allowed the team to generate an accurate breakdown of the carbon emissions of each part of the building (see Table 1), and to specify lower carbon materials where necessary.

3. RESULTS AND PRACTICAL IMPLICATIONS

The retrofit project achieved carbon neutrality in the design phase. This means that all the emissions that resulted from building operation and from the production and assembly of materials were offset by fully renewable energy sources. The construction of the project is underway. A full audit of both operating and embodied emissions from the retrofit will be conducted once the project is complete in order to verify as-built carbon neutrality. The project suggests that full life cycle carbon neutrality in retrofits is possible even in cold climates. Future similar projects should be evaluated in order to produce widely applicable guidelines for the design of carbon neutral retrofits in cold climates.

FIGURE 2. LEFT: BUILDING INFORMATION MODEL BREAKDOWN INTO THE VARIOUS COMPONENTS OF THE RETROFIT; RIGHT: SOUTH FAÇADE DURING CONSTRUCTION.

TABLE 1. ENVIRONMENTAL IMPACT BREAKDOWN (EE-EMBODIED ENERGY, GWP-GLOBAL WARMING POTENTIAL)

Building component	**Assembly area (m2)**	**EE (MJ)**	**GWP (kgCO2eq)**
External wall	210.70	160787.28	10690.92
Roof	140.40	221113.15	17908.02
Roof BIPV	126.60	590209.20	16408.63
Basement wall below grade	35.70	47124.71	1908.88
Horizontal insulation subterranean brim 1.5m	68.30	90157.37	4022.19
Basement wall above grade	50.00	66001.00	2944.50
Internal floors	252.20	172371.13	16191.24
Thermal wall	98.00	86827.02	5318.46
Solid partition walls	45.10	16391.60	1175.31
Glazed partition walls	63.50	30042.49	2064.39
Acoustic booth and stair well surfaces	84.30	2145.44	130.67
Staircase	22.60	575.17	35.03
Windows and skylights	53.50	105533.03	4823.03
Total/yr/m2 (assuming a 60 year lifespan)	**349.10**	**75.88**	**3.99**

REFERENCES

[1] Marszal, A.J., Heiselberg, P., Bourrelle, J.S., Musall, E., Voss, K., Sartori, I. and Napolitano, A., 2011. Zero Energy Building–A review of definitions and calculation methodologies. Energy and buildings, 43(4), pp.971-979.

[2] Zhou, Z., Zhang, Z., Zuo, J., Huang, K. and Zhang, L., 2015. Phase change materials for solar thermal energy storage in residential buildings in cold climate. Renewable and Sustainable Energy Reviews, 48, pp.692-703.

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Financing the retrofit of 250 million buildings in Europe – the opportunities and obstacles

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ABSTRACT

Abstract - Europe's current housing stock is both old and energy inefficient and the rate of replacement is low. Therefore, the Commission has been looking to take down barriers for increased investments and help facilitate market transformation. The starting point of the REVALUE project was the contention that increasing transparency in the valuation process, in relation to a property's energy characteristics and providing more explicit guidance to valuers, would assist in creating this business case and support the residential investment decision-making process.

Keywords: energy efficiency; valuation; green finance

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1. INTRODUCTION

In order to support the transition to a low-carbon economy, the European Commission is aiming to cut emissions from housing by 90% (compared to 1990 levels) by 2050.[1] With less than an estimated 10%[2] of dwellings meeting modern energy efficiency (EE) standards, this is certainly an ambitious target. Much of Europe's current stock is already old but will still be in use in 2050 - renovation is needed on a drastic scale. The current annual residential refurbishment rate is neither focused on energy efficiency refurbishments nor sufficient to achieve the 20% EE target set by the EU's 2020 objectives.[3] Indeed, the Commission Directive 2012/27/EU on Energy Efficiency, which aims to increase the annual refurbishment rate, would require a significant increase of investments, estimated to be between €70-120 billion. This is why the Commission has been looking to remove existing investment barriers and facilitate market transformation, leading to the question at the core of the REVALUE

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[1] European Parliament and the Council of the European Union. (2012). *Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC*. Brussels: Official Journal of the European Union, p.3

[2] European Parliamentary Research Service. (2016). *Briefing - Energy efficiency of buildings: A nearly zero-energy future?*. Brussels: EPRS.

[3] Economidou, Marina. (2011). *Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings*. Brussels: BPIE, p.125.

project. Does increasing transparency in the valuation process, regarding a property's energy characteristics, have a notable impact on the residential investment decision-making process?

1.1. Energy efficiency as a value driver?

The ultimate aim of the REVALUE project is to update the guidance for valuers to reflect energy efficiency in their valuations. Taking this guidance to market, additional income streams may be recognised, and other value drivers found, helping buyers and owners in making energy efficient retrofit decisions. Investors and financiers can begin to reflect EE in their risk assessments and cash flow projections, potentially unlocking yet more streams of finance, or resulting in adjusted discount factors.

To this end, the REVALUE project team has undertaken research by gathering and analysing data primarily, but not exclusively, in relation to residential portfolios in four European countries (UK, Netherlands, Germany and Spain). REVALUE is the largest scale initiative in Europe that has concentrated on studying the energy-value relationship, beyond the EPC label, therefore the data gathered included also information on component level, such as window quality, insulation, heating type, etc. The data gathered has been both quantitative (regression analysis) and qualitative (interviews, case studies and round tables). Furthermore, a supporting analysis of the technological solutions to support energy efficiency retrofits was undertaken.

REVALUE research also included a regression analysis to better define the link between a property's energy efficiency and its report value. The quantitative study was undertaken by experts in Maastricht University, who investigated a limited range of portfolios belonging to Registered Housing Providers (RHPs), over a period of seven years (2008-2015). The study covered six portfolios in four different European countries (the Netherlands, the United Kingdom, Sweden and Germany). In all, the analysis covered a sample of 120,000 dwellings. The results show that EE currently plays a marginal role in explaining the reported valuation of the dwelling, relative to traditional value factors, such as location or size. The results for each portfolio differed but in none did the EE contribute to a notable extent.

1.2. Making the EU's ambition achievable

Many building types within the residential sector located in low value areas are running a particularly high risk of becoming stranded assets. A comprehensive, long-term programme of planned improvements and maintenance is the best way to ensure assets aren't stranded or down-valued as expected standards of EE continue to rise. However, this can be hard to justify when capital enhancement is not likely to follow. The quantitative research from the REVALUE project did not definitively conclude that better energy performing dwellings have a recognised higher market value. Given how challenging it would be to renovate 250 million houses under current market conditions, what is needed to make the EU's ambition achievable?

2. The current situation

Working together with housing providers, to develop long-term renovation strategies for their stock, meant assessing the quality of their stock. In the four pilot countries, the housing associations' current business strategies were compared against their long-term goals and compliance requirements. Due to increasingly ambitious sustainability policies at both European and national levels, housing associations are driven to integrate energy performance objectives in their strategies and asset management programmes. Long-term goals included energy neutrality by 2050 in Berlin, and an average EPC label B by 2021 for all social housing providers in the Netherlands. However, interactions during the REVALUE project showed that, in most cases, planning to meet such targets is currently limited to just one or two budget cycles, with only aspirational explorations of longer-term vision. This is partially the result of governments not setting clear goals, instead expressing lofty ambitions, often with voluntary measures. However, setting long-term strategies can help to take advantage of economies of scale when investing. Furthermore, the analysis can present the trade-offs between the cost/energy savings of the alternative renovation ambitions – thus ultimately financing retrofits more smartly.

3. Ways forward towards more financing

The current project flows from an acknowledgement that improvements to the building stock are vital to achieving these targets as it is acknowledged that the majority of stock is sub-standard. Regulating new buildings will not do enough and so, we must focus on upgrading existing buildings to meet greater EE standards. The REVALUE research has shown some advances in terms of the links between EE and value. For the first time, it can be claimed that component-level EE information *does* affect dwelling value in the eyes of the professional valuers. Furthermore, lenders are increasingly starting to collect data on the portfolios they grant loans to. Banks are offering up to 20 base points discounts for green loans, using scorecards that are based on dwelling energy performance data. This means that thorough and consistent data collection on a dwelling's main characteristics is now a vital task for portfolio owners. Investors must ensure that the information shared with their valuers and financiers is as accurate and effective as possible to guarantee the best possible terms on loans for retrofitting. Including EE information in the property value by using accurate data allows banks/investors to adjust their assets book value, thereby directly realising gains from EE investment.

We are moving from the low-hanging fruit of upgrading light bulbs to renovating the windows in our houses. The REVALUE research has proved that there have been changes in the market, but, unfortunately, an overall market transformation takes a relatively long time. For more effective financing to become available and more green financing initiatives to come to market, it falls to the policymakers to regulate and enforce the necessary standards. Some countries are already acting – a clear example being the UK's new Minimum Energy Efficiency Standards (MEES). MEES, which came into force in England and Wales on the first of April 2018, applies to private rented residential and non-domestic property and is aimed at encouraging landlords and property owners to improve the energy efficiency of their properties by a restriction on the granting and continuation of existing tenancies where the property has an Energy Performance Certificate Rating of F and G.

Unclear policy deters investors and prevents financiers from valuing EE as fully as they could. For example, the European Commission has determined that all new builds should be Nearly zero-energy buildings (NZEBs), without providing a clear definition of what that means. This has led to general confusion, which, in turn, means that the investments and upgrades will not happen to the necessary degree.

4. Conclusions

Bridging the gap requires a multilateral solution. The conditions for investing and financing set by the EU must be adjusted to ensure a straightforward flow of the much-needed capital. Housing providers must ensure that their stock's EE information is comprehensive and consistent. Valuers are then better positioned to consider a property's energy performance in a valuation. In turn, this leads to a change in the market, providing a financial motivation for energy efficient retrofitting.

FURTHER READING

For more information on the REVALUE project, please visit the website: revalue-project.eu

REFERENCES

European Parliament and the Council of the European Union. (2012). *Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC*. Brussels: Official Journal of the European Union.

European Parliamentary Research Service. (2016). *Briefing - Energy efficiency of buildings: A nearly zero-energy future?*. Brussels: EPRS.

Economidou, Marina. (2011). *Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings*. Brussels: BPIE.

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Experiences from EU MORE-CONNECT Pilot Projects

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ABSTRACT

Abstract – within the EU Horizon 2020 MORE-CONNECT project prefabricated building elements for energy renovation of buildings have been developed, prototyped, tested and demonstrated in pilot buildings in 6 countries. This extended abstract provides a taste of the results of this work as it is documented in the relevant project deliverables. The type of prefabricated elements range from complete light façade elements, via robot concrete 3D printing to PV-roofing elements. Examples of these has been shown here in this paper and a more extensive presentation will be given at the conference.

Keywords: prefab modules; porotypes; pilot projects;

1. INTRODUCTION

This paper summarises the experiences from the energy renovation demonstration projects carried out in the context of the EU Horizon2020 MORE-CONNECT project. These projects demonstrate the implementation of new prefab technologies to lower the renovation cost and reduce the working time at the building site in 6 countries: Czech Republic, Denmark, Estonia, Latvia, The Netherlands and Portugal. As these projects are demonstrating the technologies for the first time they are referred to as pilot projects. The project comprises 5 pilot projects and 2 so-called real life learning lab environments.

The experiences cover the complete working chain from the production of the prototypes of the first prefabricated elements, the realization at the building sites - and includes the evaluation of the whole process. The compilation of experiences have been documented in four deliverables from the project, which in addition to the pilots themselves represent the results of the MORE-CONNECT project. These deliverables also form the basis for this paper. The deliverables can be downloaded in full from the MORE-CONNECT website: www.more.connect.eu.

2. PRODUCTION OF PROTOTYPES OF THE PREFABRICATED ELEMENTS

This deliverable documents the work concerning the development and manufacturing of the prototypes of the prefabricated building renovation elements by the participating MORE-CONNECT producers: BJW, WEBO, Matek, ZTC, Invela, Ennogie & Darkglobe. For each producer this documentation covers:

- Photos of the elements with comments about the details/components and production process

- Details about the production, e.g. amount, production time, etc.
- Results of quality control checks

The prefabricated renovation modules have been developed for markets in:
The Netherlands, Latvia, Estonia, Czech Republic, Denmark & Portugal

The figures below illustrates the development and testing of some the prefab elements.

Fig. 1 Preparation for the assembly test in the Czech Republic– fixing the connection elements for the air ducts and the piping.

Fig. 2 Design and construction of the first prototype elements in Estonia.

3. REALISATION OF 5 PILOT SITES

This deliverable documents the actual renovation of the pilot buildings using the prefab construction elements and other energy renovation measures. The renovation in some cases may include the partial or total removal of existing structures (facades, roofs, installations), depending on the renovation methodology (total replacement, partial replacement or addition of elements). For each country, the pilot project documentation covers:

- The total process, including recordings of the essential steps on photos and videos.
- The recording and evaluation of the working of the smart plug & play connectors in practice

The photos on figure 3 shows different stages of the installation of the prefabricated elements in Estonia.

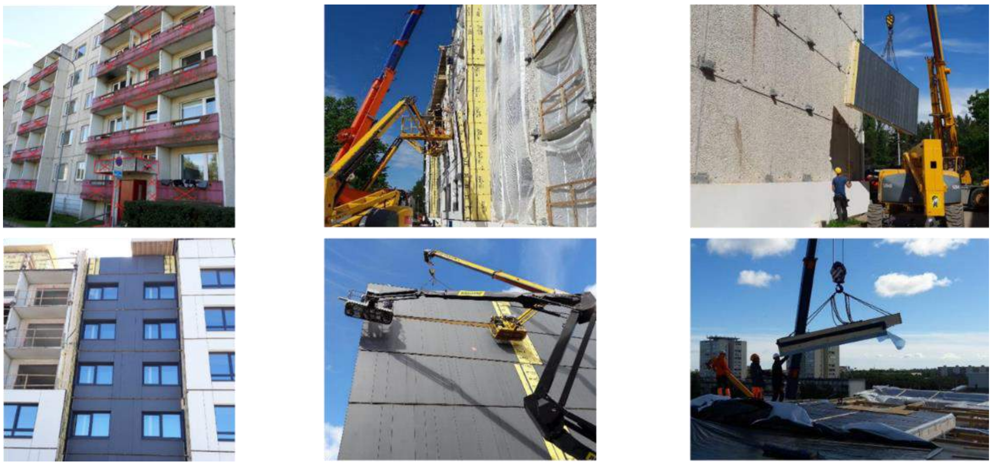

FIG. 3 INSTALLATION OF MODULAR ELEMENTS AT THE ESTONIAN PILOT BUILDING - SUMMER 2017

4. REALISATION OF 2 REAL LIFE LEARNING LAB ENVIRONMENTS

In MORE-CONNECT there are two locations where a Real Life Learning Lab (RLLL) situation were used. These RLLL situations are more suitable for the in deep testing of specific solutions like the smart plug & play connections, advanced controls, building physics, moisture behaviour, zero energy solutions and testing of special and specific materials like super insulation, biobased composites and 3D printed materials in a small scale semi-lab setting. The two RLLL settings are organized in Czech Republic and in The Netherlands.

In focus at the Czech RLLL were:

- Testing of connections among modules and of advanced control systems
- Provision of a showcase for dissemination

In focus at the Dutch RLLL were:

- Testing of prefab multifunctional facades, roofs and ‘engines’ (installation platforms)
- Monitoring on energy use and in deep monitoring on thermal comfort and health

5. EVALUATION OF THE QUALITY OF CONSTRUCTION WORKS - FEEDBACK FROM THE PILOT PROJECTS

The total renovation process was to be evaluated and analysed in two steps. A first evaluation was carried out at the end of the third year. The second will be made by the finalisation of the project. The evaluation was carried out for each of the pilots covering the phases: Design, production of elements and installation.

As an example of the lessons learned is here presented from the Danish PV-roof manufacturer Ennogie: Within More-Connect Ennogie has developed several prototypes of its Solar Energy Roof - in particular concerning methods of mounting and flashing details to create a customer and installer driven plug-and-play solution. Before starting the installation on the pilot building Ennogie completed two prototype installations. Learning from these experiences about installation methods and workmanship Ennogie changed the way cables are to be assembled and packed, which led to an increase in a 10% efficiency in onsite installation.

6. CONCLUSION

Within MORE-CONNECT extensive development of prefabricated building elements and demonstration of the implementation of these in pilot projects have been carried out in the participation countries. An elaborate presentation will be given at the conference.

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Future Comfort: Efficiency, control and consumers

Struggles to define the future of residential heating

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ABSTRACT

Heating and cooling covers about half of the world energy consumption. In order to achieve the targets of the Paris agreements, a transition in domestic heating is required. Various options are on the table. However, a targeted long term strategy is hard to achieve as efficient systems require high levels of consumer participation while consumers distrust large monopolist and tend to prefer individual or small scale solutions. Moreover, incumbent actors aim at safeguarding their assets by pushing temporary measures which might create lock in, curbing future options. The paper analyses case studies regarding (proposed) projects to create natural gas free urban areas, the alternatives that were introduced into the decision making arena, and the choices that have been made. It is concluded that the growing consensus on the importance of climate action sometimes leads to the uncritical acceptance of sub-optimal alternatives, and that this is a real problem.

Keywords: Residential heating; district heating systems, transition; governance

Introduction

For almost 3 decades, there has been a call for action to mitigate climate change. Environmentalists, supported by a growing pile of scientific evidence, called for action to avert climate catastrophe. It now seems that their argument achieved a victory. The Paris agreements, local and global climate catastrophes, often combined with more local damages related to fossil fuels, contributed to a spirit of implementing change.
As much time is lost to implement measures, many people argue that 'change should be implemented fast', an argument that seems to be in line with the urgency that environmentalists have claimed before. The call for fast action could lead to a coalition of 'green actors' and the incumbents of the energy sector, as fast action on a large scale achieving substantial results can only be achieved using existing facilities and networks of the incumbents of the energy sector. However, although such fast actions might reduce greenhouse gas emissions quickly, they might prevent the introduction of future solutions that reduce more, have a more local character, and facilitate a circular economy.
The paper will illustrate this analysing case studies regarding the transition in heating. The case studies are in part 'works in progress'. The focus is on attempts to develop locally

available heat and cold sources to replace natural gas as a fuel, vis-à-vis attempts to roll out large scale centrally controlled heating systems.

The problems of a heat transition

Heat grids could be interconnected, and could be fuelled by the waste heat of the fossil fuelled industry. Such solutions meet with public resistance: consuming ‘fossil heat’ is suspect. As such, there is no problem to use heat that would otherwise be released in the environment: on the contrary, environmental damages due to thermal pollution could be prevented. However, these kinds of solutions endanger the process of transition twofold:

- They improve the business case of fossil fuel business activities, postponing the phase out of these activities
- They ‘lock in’ specific technological solutions, (large scale, high temperature heat, specifications derived from fossil fuels production, no individual control), that create barriers for the transition to renewable heat production and distribution.

Large scale heating (& cooling) systems, combined with stimulation/facilitation of insulation of dwellings and utility buildings, can only be successfully introduced if a wide consensus of real estate owners can be achieved. In the Netherlands, self-homeownership has rapidly increased, creating more need for consensus: In the past 15 years, the number of families that owned their own home in the city of The Hague increased from 32 to 48 %. As a result there are far less real estate investors/public housing companies that could easily act as the launching customer for a heat grid. For introducing heat grids, the consent, or even better, enthusiasm of home owners is crucial. As the construction of a heating grid is the main cost factor, every non-connection hardly diminishes costs, while directly cutting income for the heat grid operator.
However, there are clear signs that residents prefer solutions that provide them with far more control of their energy consumption/production than is offered to them by a connection to a heat grid operated by a monopolist.

Enforcing change or creating interaction?

Technology is neither ‘Manna from Heaven’ nor prescribed by the ‘state of scientific knowledge’. A successful new technology is the stabile result of a process of heterogeneous engineering that reorders materials, machines, actors and institutions; a socio-technical process in which part of reality is reordered. However, such reordering is neither a process solely determined by one actor, such as the designing engineer, nor a process that has one goal, that is shared by all participants. Efficiency, no matter if it is defined as cost efficiency, energy efficiency or environmental efficiency, is often the dominant design criterion for engineers. Based on a definition of efficiency, engineers design ‘the best’ heating system. But as this design criterion is not considered to be the only relevant criterion by all stakeholders, the risk of conflict is imminent. What is lacking in the way heat system designers perceive their consumers? Heat consumers want to be in control:

- They do not want to be dependent on a single supplier that can unilaterally prescribe tariffs, is expected to be opaque and inefficient
- They do not accept limits on their behaviour, created by a heating system. For example citizens want to be able to save money when they are out of cash, or prefer to have only minimal heating

The paper will present and discuss work in progress regarding various initiatives to develop new heating plans for urban areas. After analysing local case studies to analyse conflicts between citizens’ initiatives…… How can citizens be facilitated to develop plans themselves and reach consensus with their neighbours regarding heating their homes? Basic choices

have to be made regarding the scale of systems (individual-block-urban area), open- or closed systems, and the solidarity and consensus that is required.
The paper concludes that transparency is a key issue for long term success of energy transition attempts. Citizen initiatives contribute to transparency and trust, while secrecy regarding the interests of incumbents, and hidden attempts to integrate their interests into a new system rages suspicion and tensions.

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Organizing building capacity for NetZero renovation

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ABSTRACT

Dutch existing building stock has, according to Dutch governmental policy derived from the European goals, to be renovated towards NetZero in about 2050. However, this goal will not be reached without new digitalized tools, like BIM, 3D scanning and printing, automation and robotization of production processes. To make automation and robotization possible, standardization must be developed through the design, production and maintenance process. But there is already a standardization present in the current building stock, that can be put to use. For the professionals throughout building industry this means that new proficiency and new knowledge has to be achieved. 21st century skills have to be developed, but only after the 21st century skills for professionals have been researched and defined. This paper aims at explaining the interconnection between ICT innovation, recognizing patterns in the building stock and development of personal skills and proficiency for automation in Dutch NetZero building renovation.

Keywords: BIM, NetZero Renovation, 21st century skills

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1. INTRODUCTION TO ORGANIZING BUILDING CAPACITY

The Dutch existing building stock is supposed to be NetZero in the year 2050, with an intermediate goal of 49% in 2030, according to Dutch governmental policy (Klimaatberaad, 2018). This means that about 6.7 million dwellings have to be upgraded to NetZero Energy. It is shown that the capacity of Dutch Building Industry is intended to grow, but not as fast as necessary for the upcoming tasks (Hoek et.al. 2018).

This complex technical challenge can be simplified by using a typology based approach for dwellings, representing the majority of Dutch building stock. However, it is already known that the necessary building capacity for performing such a gigantic task is not available nor will it be realistically become available, unless automation is pushed to the limit (Van Nunen 2017). The goal of the paper is to show to what extend existing building capacity can be organized for NetZero renovation and to what extend building capacity has to be automated and robotized to achieve public policy. Finally the papers shows which personal skills and knowledge are needed to make professionals in the building industry fit for renovating towards NetZero energy renovation.

The rate of success for upscaling NetZero energy renovation lies within unlocking the data of the housing stock and showing opportunities based on data. When projects are still being based on the scale of a complex there is no room for expanding the market for renovation solutions. The overhead costs of a project put a burden that is too big. There is dire need to recognize repetition within the building stock. This repetition allows us to create solutions that are not only applicable for one complex, but for instance for 30 percent of all dwellings in the Netherlands. The overhead costs (sometimes up to 50 cents per invested euro in traditional projects) will diminish because of this repetition. With BIM we can gather, document and analyze data that visualizes the repetition. That way general features of the building are known, and can be used as a starting point for (deep) renovations, towards NetZero and beyond. It becomes the base for product development as well as concept development

Automation alone will not change the building industry. If every complex or every building at its own needs to be documented, it still is a lot of work, even if building industry can automize or robotize the task at hand. This paper will address a new view at the Dutch building stock which will allow automation for renovation solutions on a much larger scale. The repetition goes beyond the complex but searches for similar components, like roofs or facades in a neighborhood or town. All the knowledge of one roof can then be extrapolated to a similar roof in another street or even another city.

To facilitate upscaling based on repetition, this paper addresses the means in automation, like BIM, standardizing, industrialization, customization, 3D scanning and printing and robotizing, and their potential aid to enlarging building capacity. These means will be discussed in the perspective of knowledge transfer, innovation in building industry and the personal 21st century skills that professionals will have to develop differently from the skills that were present before in the 2000. The digitalization came through in building industry. There will be major changes in means and in skills handling the new means. This gives new input and new directions for institutes for higher education in architecture, building and construction.

1.1. Problem description

The renovation task is eminent. 90% of the existing stock remains but needs to be renovated towards NetZero. The Paris agreement points toward a 80-95% CO_2 reduction. The building industry, which in The Netherlands accounts for 21,5% of the total CO_2 exhaust, has an enormous task to full fill. On one hand a planned expansion of 1 million buildings and at the other hand all existing buildings that need to be renovated towards NetZero before 2050. The current rate of energy saving in non-profit housing for instance is too low (Filippidou

2018). The renovation task translates into 270.000 buildings a year, 5.200 per week, or simply 1.000 renovations a day (Nunen, 2017). This encounters several barriers:

- At this moment the availability of construction workers is low and the amount keeps decreasing (Economisch Insituut voor de Bouw (EIB), 2018) . There is need for 70.000 extra workers, just to fulfill the current building activities. The NetZero renovations need another 70.000 extra workers, if we work in the same way as we do now (Economisch Instituut voor de Bouw (EIB), 2017)
- In 2017, 63.000 new buildings were built per year (CBS, 2018) , but also 23.150 buildings were demolished (CBS, 2018), resulting in a net growth of approximately 40.000 buildings. This is barely enough for the needed expansion of the Dutch housing stock, which is forecasted to grow with 1 million in the next 25 years. Serious upscaling of new build production is, even according to contractors, not possible. This means that most of the current stock will remain. But also that the part that remains has a need for improvement.
- If building professionals accept the fact that 1.000 buildings a day are needed to be renovated this will have a huge impact at the rest of the building industry. For example 1.000 buildings a day, results in 1.000 permits, and 1.000 facades a day. Current timber workplaces can hardly produce 1.000 a week. So not only contractors are in need for a scale up, also the industry that provides the product needs to grow. (Huygen - BouwhulpGroep - Hogeschool Utrecht, 2017) (TKI-RVO rapport). Typical fail factors for NetZero renovation are widely spread amongst professionals in the building chain (Ravesloot, NetZero Housing Renovation, Fail factors for upscaling and market expansion,, 2016). The cost aspect is also holding back the upscaling. NetZero renovations of complete buildings vary between €70.000- 100.000, which is expensive, even with the quality added. The value added to the building is not in line with the costs. There is an efficiency gap. Notwithstanding this gap, the availability of money is for much households a barrier. The gap however can be closed soon with use of BIM and robotization 2016b (Ravesloot, Accelerating the Speed of NetZero Renovation with BIM, 2016)
- There is no base to come to a decision, especially in the consumers market. There are no examples. Professional parties like housing associations have some knowledge, but the owner-occupant generally lacks this knowledge. So there has to be a way to show the complete quality and cost of a (net zero) renovation. Decision making itself is a major issue in the professional Dutch building practice, there also innovation is needed (Ravesloot, Innovating process factors in improving sustainability of suburban building stock, 2012).

Digital information about buildings allows for all these aspects. Whether it is a maintenance task, a renovation task, or just a simulation of possibilities, the use of building information modelling seems unavoidable and necessary (Ravesloot, NetZero Housing Renovation, Fail factors for upscaling and market expansion,, 2016) (Ravesloot 2016a). With building information modelling many fail factors can be turned into success factors throughout the

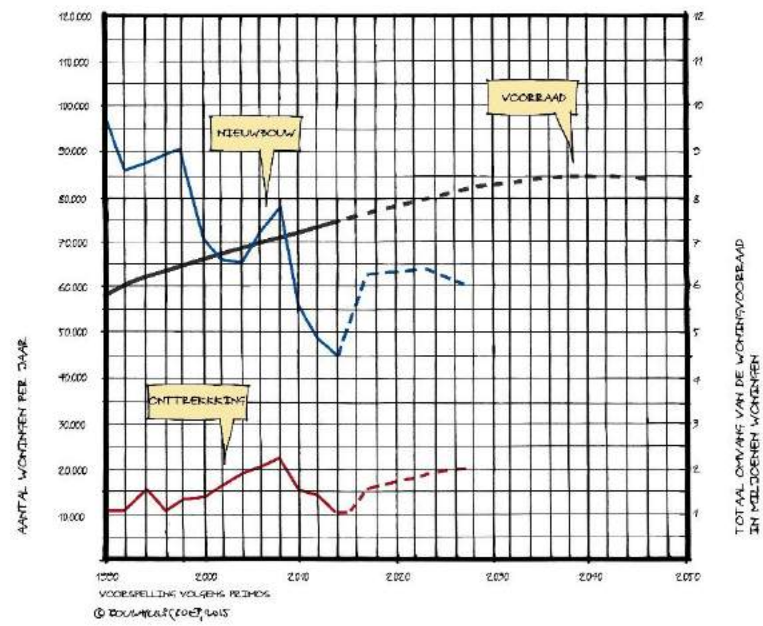

Figure 1: predicted net growth of Dutch building stock

design and supply chain. We see the following advantages using building information modelling:

A. communications through 3D models provides common base for collaboration, avoiding typical problems like different serial numbers in drawings, misinterpretation of 2D drawings, misinterpreted building knots from 2D drawings.

B. design alternatives from different technical and economical perspectives can be optimized. Parameters can be simulated in countless design alternatives, with reporting of effects on design and costs.

C. information of the construction phase can be used earlier in the design process.

D. co-creating partners can influence the design decisions earlier in the process.

Use of BIM is optimal in integrated contracts involving Life Cycle Costing and Total Cost of Ownership (TCO) calculations, prior to traditional procurement on lowest price. At this moment these kind of contracts are not common, and often be looked upon as complex.

1.2. Research methods and approach

The variable in this research paper is the extent to which the building industry professionals have the skills and knowledge (proficiency) to use digitalization to improve and enlarge the building capacity for Dutch NetZero renovation. Influencing failure and success factors are categorized from literature research. This categorization is done from the perspective of contemporary working methods opposed to new technologies as BIM, scanning and 3D printing.

The main research question is:

Which proficiency in digitalization is needed by Dutch building industry professionals to positively influence factors improving and enlarging building capacity in Dutch NetZero renovation?

Through interviews with experts in Dutch NetZero renovation best practices are listed. Typical technical and economical specifications are researched from documents in the projects In these projects the categorized factors are identified. In a comparison of projects on a linear timeline, the projects are compared. The question is to what extent available innovation in digitalization will improve the Dutch building capacity for NetZero renovation. Then the question is what this would mean for the knowledge and skills of Dutch building professionals?

2. 21st CENTURY SKILLS FOR NETZERO RENOVATION

Because the amount of buildings that have to be renovated, more expertise is needed in this field of building activity. At this moment literature depicts several trends going on with renovation:

- Need for energy efficient renovations (Nunen, 2017)
- Demand for circular renovations (Gemeente Rotterdam, 2017)
- Rising individualism (Projectgroep DEPW, 2012)
- Affordability of living (Ministerie van Binnelandse Zaken en Koninkrijksrelaties, 2018)
- For rental as well as privately owned market (VNG, 2018)

If we see this as a wish list, a different approach is needed, because the traditional renovation approach is too expensive, has no room for individual choices and is always based on the complex as one entity. Whereas the solutions are needed in a series of one, and based on a component. But dividing a building into components just adds the amount of data. If seven components are discerned, we are not discussing 7.5 million buildings, but over 50 million components. Digitalization with Building Information Modelling is needed to organize and facilitate this. Based on the research of typology, the basic information is already known, and design, preparation and implementation can be managed by BIM. It also allows for a market based on push, rather than pull (Ravesloot 2012, 2016).

BIM as standard

This means that BIM would become the standard in Dutch NetZero renovation, and Dutch building professionals would need the necessary knowledge and skills of BIM for in 21st century renovation. BIM is a software platform providing communication, exchange and interchange of building process related information, based on sharing of data. The use of BIM can provide a standard for automatization (Volk at.al. 2014). Less risk on human failure in processing data and information is proven by BIM. Less hours on labor and management can be presumably be achieved by using BIM. BIM does not start or stop when building activities are up hand, it is an ongoing way to manage al building related data. From design drawings, to construction calculations, but also the maintenance contracts, the revised drawings of prior renovations, and even the simulations of the upcoming plans.

BIM is part of the disruptive Information Communication Technology (ICT), so the question is not if, but when BIM will be the standard in building industry. Once it is, the production of NetZero renovation can be accelerated, hence leading to less cost.

Dividing the housing stock

The renovation task is huge. The current approach is a complex based approach, often applied by housing associations. But this is a tedious way of observing the complex, describing characteristics, designing plans and organizing the market. It is too work consuming and therefore not efficient. Similar buildings can be regarded as a variation on a type. It doesn't matter whether the building is 10 centimeters more wide or has an extra window. The principal details are what makes the building the building. So if we take another approach to look at buildings, perhaps other solutions and processes emerge.

A building consists of several parts that, combined together fulfil a function. In the past several researchers describes the division of a building into parts (Hermans, 1995), (Eekhout, 1997), (Oostra, 2001)) all from their own perspective. To understand the dynamics of different parts, or for the purpose of development. None of these divisions use the same name. Looking at these three studies and the dictionary, we will use the term component.

A component is a series of building products that, when combined fulfil a function. The reason to look at a part of a building and not the complete building has two advantages. First of all, the level of a component is to be overseen, or even S.M.A.R.T. It is more easy to discuss the performance of a roof than the performance of a complete building. Second the scale of repetition is much higher. A building has much more variables, so the chance a building with all the same variables, will occur is limited. However, when only a roof or façade is regarded much more repetition is possible.

At Rotterdam University of Applied sciences research started to discover the possibilities of a component based approach of the renovation market. This research starts with a cross section of the city of Rotterdam. That gives us a part of the city, which is divided in buildings with components that are similar. Based on this similarity solutions can be developed, but not aimed at a complex of 100, but with a potential repetition of millions.

Dividing the housing stock in a typology or archetype is nothing new, this has been done for years. But leaving the structure of a complex behind opens new opportunities. Industrialization on the component level, development of circular components are for example features based on the production level. But also financially there are new possibilities. Only a component instead of a complete building needs less money. Even financial instruments or lease constructions are more likely to succeed on a component level than for a complete building.

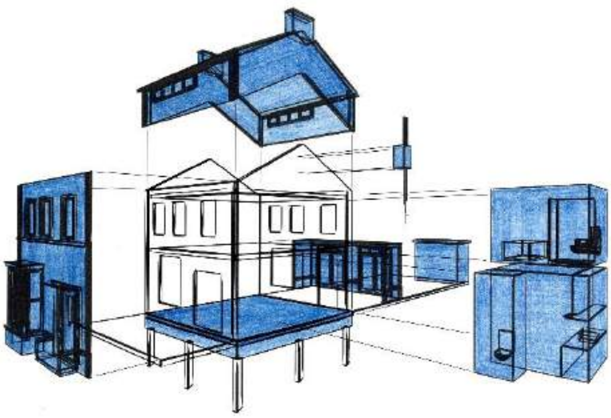

Figure 2: Component Renovation

But component based thinking increases the amount of data. Nowadays information is stored on the complex. So 100 buildings together. But if one building can be divided in 7 components, and each building needs to be documented it can no longer be done manually. The need for a data model is clear.

Renovation to the next level

With components as guiding entity, a new way of renovation can be introduced. First of all the pace of the renovation can follow the pace of the occupant or the pace of the building. For example when windows need to be replaced, the replacement of the component faced becomes an opportunity. With the component façade the energy consumption can drastically be reduced. But all the other components remain in place. That way no materials are wasted before their life span is over.

This adds to the second advantage of Component Renovation, the possibility to develop components with specific qualities. Based on the characteristics of a type of roof, a circular edition could be developed, or a luxurious edition, but also a low cost or an edition with a limited life span. The component level allows for component development instead of building development. This opens doors for small and medium enterprises (SME´s), to develop their own components. Key to component renovation is making sure that single components can be combined. Using BIM the different solutions can be interchanged.

And it is not only the development that can be realized part by part. The use of components allow people to choose form a range of options. Everyone can pick the component that suits his best interest. When a person wants to distinguish himself from the rest, a new façade can be chosen, whereas someone else chooses for the most sustainable façade. The component based approach allows for al these solutions. From a legislation point of view it can be asked whether everything is allowed, for example can every individual choose its own color, not regarding the results of the architecture? With BIM this can also be demonstrated. when all data is known images of buildings and simulations of new facades can be shown up front, and add to the decision making.

One of the main barriers of the upscaling of net zero renovation are the costs. A complete building renovation will cost about 80.000 euro or more. These kind of amounts are not readily available and specially not for individual owners. The current price of a component lies at 10.000-20.000, which could more easily be assembled then 80k. But because the scale of repletion is much larger, it is likely that the costs will diminish.

The previous advantage already mentioned the owner-occupant. In the Netherlands this accounts for about 5 million dwellings. With the component based approach the kind of ownership is no longer an issue. Housing association, owners, project developers and investors can all be targeted at their own specifics. This makes component renovation one of the few solutions that can make the complete housing stock sustainable. But to reach the individual owners, they have to get all the necessary information. This is where BIM comes to use again.

The professionals from building industry handling BIM need to become more mature in their organization and more proficient in their personal skills and competences. Stel (2015) shows from a survey amongst Dutch building industry professionals how very BIM proficient professionals differ from BMI newbie’s, The extend of:

- communication in the organization about BIM;

- sharing information about BIM;
- use of BIM for improvement of internal organizational collaboration;
- help from colleagues in the use of BIM;
- use of BIM for improvement of external organization collaboration;
- experience with BIM projects;
- enthusiasm to others to encourage to use BIM;
- communication about BIM Outside own organization;
- general actions to always improve BIM implementation.

It can be concluded easily that the above mentioned skills and competences are not only related to BIM. The skills and competences are not on the level of technical knowledge and technical proficiency, but more on the soft factors in human interaction during collaboration in engineering. This gives important information on curricula for building engineering education.

3. CONCLUSION

The NetZero renovation of 1.000 buildings a day is a task the building industry is not equipped for in 2018. Not in the decision forming process, not in the preparations and not in the production. The building industry lacks people to organize the process and do the building work, because most labor is done manually. Smart tools allow each individual to make smart choices for their NetZero home renovation. The consequences (cost, energy saving, maintenance, etc) can be seen in the perspective of finance and total cost of ownership.

Dividing the housing stock in components is a new way to look at the task that lies for us. We can chose which component to improve. With Building Information Models these choices can be transformed into plans, ready for permit process, and even for production. But the current employees are not equipped for this task and need another mindset. The goal of this research is to illustrate the need for automation of the renovation process and in the same time show possibilities to renovate step-by-step. The success of upscaling NetZero renovation depends on the availability of data and renovation opportunities. They are Decision forming tools for renovation. These tool have to be used by building industry professionals who can organize themselves with a high standard in maturity and with highly developed soft skills and competencies making them highly BIM proficient.

REFERENCES

CBS. (2018, 07 03). *Voorraad woningen en niet-woningen; mutaties, gebruiksfunctie, regio*. Opgehaald van Statline: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81955NED/table?ts=1530609004531

CBS. (2018, 07 03). *Voorraad woningen en niet-woningen; mutaties, gebruiksfunctie, regio*. Opgehaald van Statline:

https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81955NED/table?ts=1530609311391

Economisch Insituut voor de Bouw (EIB). (2018). *Klimaatbeleid en de gebouwde omgeving (1).* Amsterdam: EIB. Opgehaald van https://www.eib.nl/pdf/EIB-notitie_Klimaatbeleid_en_de_gebouwde_omgeving_(2).pdf

Economisch Instituut voor de Bouw (EIB). (2017). *Trends op de bouwarbeidsmarkt 2017-2022.* Amsterdam. Opgehaald van https://www.eib.nl/pdf/Trends%20op%20de%20bouwarbeidsmarkt_web.pdf

Eekhout, M. (1997). *POPO: Proces Organisatie voor Product Ontwikkeling.* Delft: Delft University Press.

Filippidou F. (2018) Energy performance progress of the Dutch non-profit housing stock: a longitudinal assessment. A+BE | Architecture and the Built Environment, [S.l.], n. 14, p. 1-256, June 2018. ISSN 2214-7233. https://doi.org/10.7480/abe.2018.14

Gemeente Rotterdam. (2017). *Rotterdam gaat voor circulair.* Rotterdam.

Hermans, M. (1995). *Deterioration characteristics of building components.* Eindhoven.

Hoek T. Van, Jorrit Bakker J., Errami S. (2018) Sustainable Urban Delta, Ontwikkelingen en investeringsopgaven in beeld, Economisch Instituut voor de Bouw EIB.

Huygen - BouwhulpGroep - Hogeschool Utrecht. (2017). *NOM-woningrenovatie op weg naar een kwaliteitsproduct .* Utrecht: TKI-Urban Energy.

Klimaatberaad. (2018, 07 03). Opgehaald van Klimaatakkoord: https://www.klimaatakkoord.nl/

Ministerie van Binnelandse Zaken en Koninkrijksrelaties. (2018). *Nationale Woonagenda 2018-2021.* Den Haag.

Nunen, H. v. (2017). *#Duurzaam Renoveren, hoe het wonen stap voor stap duurzaam wordt.* Rotterdam: Hogeschool Rotterdam Uitgeverij.

Oostra, M. (2001). *Componentontwerpen, De rol van de architect in productinnovatie.* Delft: Eburon.

Projectgroep DEPW. (2012). *Duurzame projectontwikkeling na 2015: adaptieve renovatieconcepten - EOS.* Voorburg: Rijksdienst voor Ondernemend Nederland.

Ravesloot, C. (2012). Innovating process factors in improving sustainability of suburban building stock. In D. G. et.al., *COST 0701 Improving the Quality of Suburban building stock.* Leiden: A.A. Balkema Publishers .

Ravesloot, C. (2016). Accelerating the Speed of NetZero Renovation with BIM. *Proceedings SBE16 Sustainable Built Environment: Transition zero.* Utrecht: Ivo Opstelten, Ronald Rovers, Nadia Verdeyen, Andy Wagenaar (eds.).

Ravesloot, C. (2016). NetZero Housing Renovation, Fail factors for upscaling and market expansion,. *Proceedings SBE16 Sustainable Built Environment: Transition zero.* Utrecht: Ivo Opstelten, Ronald Rovers, Nadia Verdeyen, Andy Wagenaar (eds.).

Stel Rosanne (2015) De grootste invloeden op de implementatie van het Bouw Informatie Model in de Nederlandse bouwsector, bachelor of engineering thesis, Rotterdam University of Applied Science, Research Center Sustainable Harbor Cities;

VNG. (2018, juni 12). *Innovatieve aanpakken koopwoningen*. Opgehaald van Vereniging Nederlandse Gemeenten: https://vng.nl/innovatieve-aanpakken-koopwoningen

Volk, R.; Stengel, J.; Schultmann, F. (2014): Building Information Models (BIM) for existing buildings – literature review and future needs - Automation in Construction 38, pp.109-127, DOI: 10.1016/j.autcon.2013.10.023.

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Review on the state-of-the-art of deep energy renovation and pre-fab systems in EU-funded projects

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ABSTRACT

The goal of this paper is to analyse state-of-the-art solutions for deep retrofit design methodology using prefabricated systems, thus including 1) the diverse technological solutions adopted and 2) the optimization objectives, that have been developed, tested and employed over the last decade of EU-funded projects. A total number of 31 EU-funded projects (H2020, FP7) and their developed solutions in the time frame 2008-2020 were reviewed. As a general criterion for the projects' selection, we focused on projects able to deliver insights on advanced integrated design method, dynamically including production, monitoring, control and operation of smart components and systems adopted for deep retrofit and pre-fab systems. This paper has the overarching aim to provide critical insights that could be further developed and applied to successfully meeting expected 2020 energy targets.

Keywords: H2020 projects, deep energy renovation, prefabricated systems

1. INTRODUCTION AND APPROACH TO THE REVIEW

Figure 1 shows a list of 31 recently concluded or ongoing EU -relevant and -funded projects (2008-2020) that deal with state-of-the-art solutions for deep renovations and prefabricated systems, including advanced technologies and systematic renovation strategies and smart services exploited during the design, execution, and maintenance phases of the retrofit process.

1.1. Critical review on most adopted technological solutions

The revised 31 EU-funded projects have been categorized and critically evaluated based on 10 state-of-the-art technological solutions, as illustrated in Table 1, including:

1. Prefabricated systems
2. Smart Building Management Systems (BMS) and ICT integrated solutions
3. Heating Ventilation and Air Conditioning (HVAC) integrated solutions
4. Renewable Energy Source (RES) integrated solutions
5. Building Information Modelling (BIM) and Building Performance Simulation Model (BPSM)
6. Advanced Geomatics
7. 3D printing
8. Advanced Materials
9. Smart Connectors
10. Multi-benefit approaches

Table 1: *Key state of the art technologies for the reviewed EU-funded projects that deal with pre-fab systems for deep renovations.*

Project	Pre-fab	BMS - ICT	RES	BIM BPSM	Multi-benefit	HVAC	Advanced geomatic	3D print	Smart connector
A2PBEER		√							
ABRACADABRA	√		√		√				
ADAPTIWALL	√								
BERTIM	√			√			√		
BRESAER	√	√	√						
BuildHEAT	√	√	√		√	√			
CETIEB		√							
E2ReBuild	√								
E2EVENT	√	√	√			√			
EASEE	√			√			√		
Eensulate	√								
HERB	√		√			√			√
IMPRESS	√							√	
INSITER							√		
INSPiRe	√		√						
MeeFS	√	√	√						
MORE-CONNECT	√	√	√	√	√	√	√	√	√
NewTREND				√					
NeZeR					√				
P2ENDURE	√			√		√	√	√	
OptEEmal	√	√		√	√		√		
REFURB		√	√		√	√			
REnnovates	√	√	√	√	√	√			
RetroKit	√	√	√			√			
RE4	√	√		√			√		√
smartTES	√		√			√			
TES	√		√			√			√
TransitionZero				√	√		√	√	
VEEP	√						√		√
ZEBRA 2020					√				
4RinEU	√	√	√	√	√	√			

1.2. Critical review on most adopted optimization objectives in EU-funded deep renovations

Furthermore, the revised projects adopting state-of-the-art technologies and pre-fab systems in deep renovations have been revised based on 9 key optimization objectives:

1. Energy efficiency: reduction of the energy required for heating, cooling, ventilation.
2. Cost-effectiveness: increase building performance in relation to its operational costs.
3. Access to the market: enhanced conditions for the penetration of technologies.

4. Comfort: increased perceived IEQ, IAQ, and satisfaction for the building occupants.
5. Low-intrusiveness: disturbance reduction for the occupants during renovation.
6. Product and process: enhanced off-site manufacturing and on-site installation.
7. Health: reduced health-related problems and indoor wellbeing for the occupants.
8. Aesthetic: increased quality of fixtures, including increased property value.
9. Maximizing RES: increased integration of renewable energy sources in the modules.

Table 2: *Key optimization objectives for the reviewed projects that deal with state-of-the-art technologies and pre-fab systems for deep renovations.*

Project	Energy efficiency	Cost	Access to market	Product and process	Comfort	Low-intrusiveness	Health	Aesthetic	Maximizing RES
A2PBEER	√	√							
ABRACADABRA	√	√	√						
ADAPTIWALL	√								
BeAware	√								
BERTIM	√	√			√	√	√	√	
BRESAER	√	√	√	√	√	√	√		
BuildHEAT	√		√	√	√		√		√
E2ReBuild	√	√	√	√		√			
E2EVENT	√	√		√		√			
EASEE	√					√		√	
Eensulate	√	√	√		√				
HERB	√	√	√						
IMPRESS	√							√	
INSITER	√								
INSPiRe	√				√				
MeeFS	√	√							√
MORE-CONNECT	√	√	√	√					
NewTREND	√								
NeZeR	√		√						
OptEEmal	√	√	√		√				
P2Endure	√	√	√	√	√		√		
REFURB	√	√	√						
REnnovates	√								√
RetroKit	√		√						
RE4	√			√		√			
SMART-TES	√								
TES	√								
TransitionZero	√	√	√	√		√			
VEEP	√	√		√			√		
ZEBRA 2020	√		√						
4RInEU	√	√	√	√	√	√	√		√

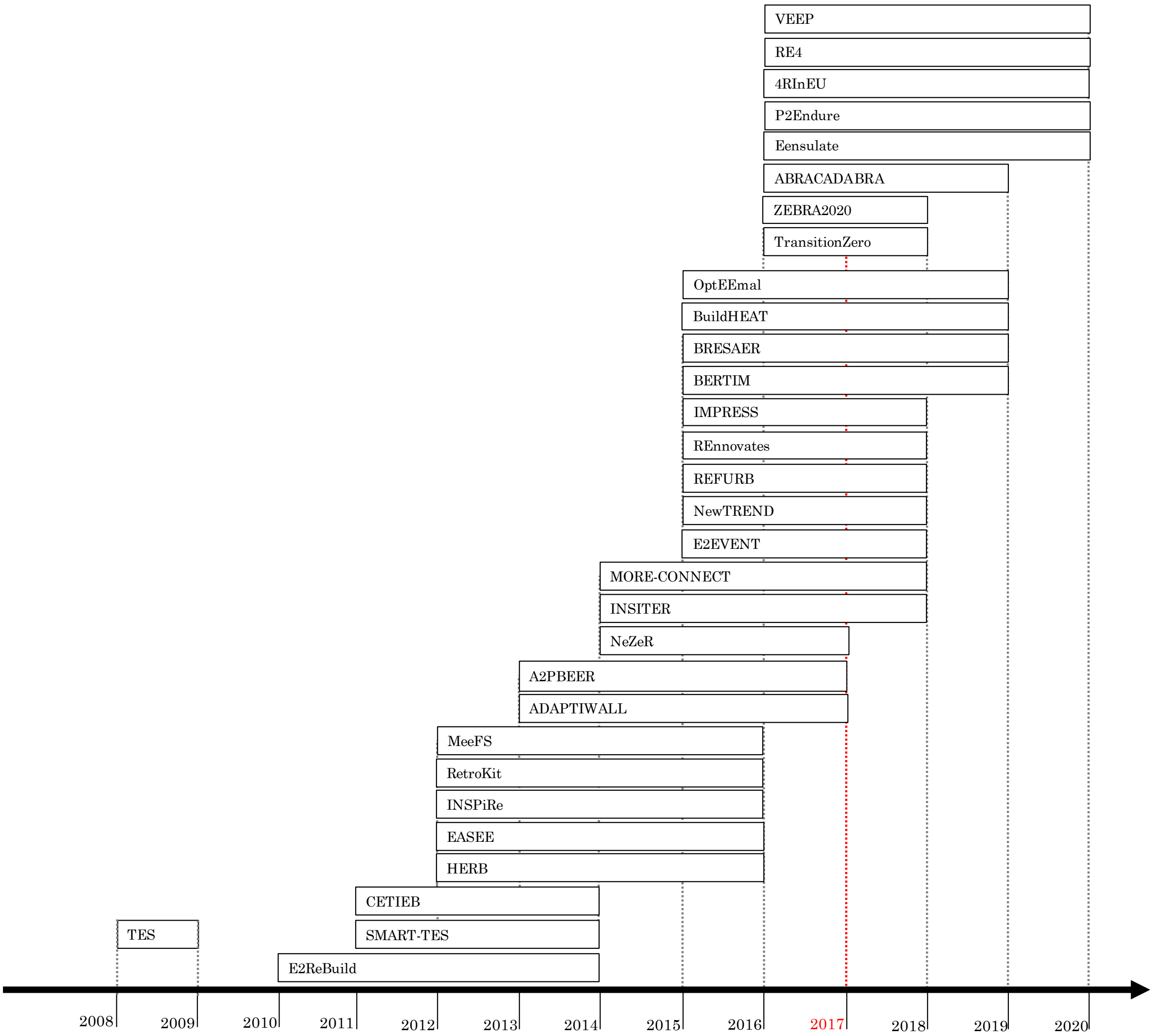

FIGURE *1*: LIST OF THE 31 REVIEWED EU-FUNDED PROJECTS THAT DEAL WITH STATE-OF-THE-ART DEEP RENOVATIONS.

CONCLUSIVE REMARKS

This work is not intended to constitute a comprehensive review of every potentially relevant project from H2020 or IEE dealing with retrofit practices, technology innovation or market uptake. This paper has the overarching aim to identify the diverse technological solutions adopted and optimization objectives that could be further developed and applied in future EU-funded projects thus successfully meeting the expected 2020 energy targets.

FURTHER READING AND REFERENCES

This paper is an extract and further elaboration of a public deliverable "Report on the state of the art of deep renovation to nZEB and pre-fab system in EU" developed in the context of the ProGETone Project (https://www.progetone.eu/). The review draws mainly from EU-funded project's sources such as websites, public available deliverables, and review activities executed in correlated on-going EU-funded projects (https://www.more-connect.eu/; https://www.p2endure-project.eu/en, https://www.insiter-project.eu/en).

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TYPHA Renewable Resource from Rewetted(Peat)land

Exploring a new locally produced, biobased & circular solution for energy efficient buildings

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ABSTRACT

Abstract – As a result of the Paris agreements considerable efforts are being made world wide to diminish CO_2. Within the EU a great effort is put in making new and existing buildings energy efficient. In the Netherlands the energy transition has gained momentum with the announcement in March 2018 made by the Dutch central government to end the retrieval of liquid gas from the Groninger fields in 2030. This has created a societal sense of urgency, together with the negotiations for the Dutch Climate agreements preparing for the UN Climate Change Conference in Katowice later this year. Additionally the Dutch government has indicated a timeframe for the switch towards a circular economy by 2050.
This means that in the design for new build or transformations of buildings the consequences of both transition agenda's will have to be considered, since these buildings will last for 30 to 40 years or more. As a result the (composition of) materials used in construction to make buildings energy efficient will have to be reconsidered; in order to prevent substantial future problems. This leads to additional requirements for building materials and components. In this changing context the potential for the introduction of a new insulation material is being investigated, made of locally grown biomass from the swamp plant Typha.
This paper presents intermediary results based on desk research, results of material property research, the first pilot projects and discussions among stakeholders as part of a feasibility study in the InterReg VA project 'Bio-economie in the Non-Food sector'. It explores the potential to diminish CO_2 emissions in construction and prevent future re-use problems.

Keywords: Biobased building products; Typha; energy efficiency; circular

1. Introduction

As a result of the Paris agreements considerable efforts are being made within the EU to make new and existing buildings energy efficient. In the Netherlands additional momentum has been gained for the reduction of CO_2 emissions as a result of induced earthquakes in Groningen, in the north of the Netherlands. The end of the retrieval of liquid gas from the Groninger fields in 2030 creates a societal sense of urgency needed for the energy transition. Currently plans are being negotiated for the Dutch Climate Agreements, which should add up to the ambitions to meet 49% reduction of CO_2 emissions in 2030 compared to the level of 1990. Additionally the Dutch government has indicated the timeframe in which the switch has to be made from our current linear economy towards a circular one. In 2030 50% of virgin resource use has to be eliminated, and in 2050 waste should have become obsolete.

This means that since a considerable amount of buildings that are now constructed or transformed will last well into this 30 to 40 years period, they will be transformed anew or taken down in an era when waste has to be diminished considerably or is no longer tolerated. Therefore it becomes urgent to reconsider the sorts and types of materials used in construction to make buildings energy efficient; otherwise substantial future problems may occur. This paper explores the potential of a new insulation material made of a locally grown biomass from the swamp plant Typha. Recommendations will be made for implementation and further research.

1.1. Research method

Desk research, evaluations of the first pilot projects and discussions among stakeholders made as part of a feasibility study part of the InterReg VA project 'Bio-economie in the Non-Food sector'.

Based on three pilot projects realised in Germany and one in Italy the potential for the northern provinces of the Netherlands is explored.

TABLE 1. TABLE TYPHA PILOT PROJECTS

period	TYPHA PILOT PROJECTS		
	project	**location**	**publication**
2008-2011	Restauration project	Pfeifergasse 9, Nürnberg (G)	Fraunhofer (2011)
2014	Energy efficient renovation Haus Kump	Münster (G)	https://www.ibp.fraunhofer.de/en/Expertise/Hygrothermics/projects/Energy-efficient-renovation.html http://www.demozentrum- bau.de/ messtechnik/bauteil.php?ms=FWZ_M6
2015	Demonstration pavilion	EXPO 2015 in Milano (I)	http://www.youtradeweb.com/2015/07/le-costruzioni-sono-in-una-palude-evviva/
2017	Wellness center Bora hotel	Radolfzell (G)	https://www.german- architects.com/ de/pages/praxis/praxis-48-13
2018	Renovation of detached house	Bugewitz (G)	https://www.moorwissen.de/de/paludikultur/imdetail/ umsetzungsbeispiele/gaestehauskamp.php

1.2. Evaluation framework

Two sorts of criteria are necessary to evaluate the suitability of Typha insulation within the context of both the ambitions to reduce CO_2 emissions and the ambitions to create a circular economy (Oostra 2018):

1. to improve the CO_2 footprint of building activities. The following aspects need to be considered: the growth & harvesting of the material, processing of the material & transport and the use of rest streams.
2. to avoid or diminish problems related to the reuse and recycling of components and materials from construction, by considering three issues: (1) the possibilities for recycle and reuse of the materials e.g. to insulate buildings, (2) the possibilities to replace fossil fuel based (insulation) products with biobased alternatives, and (3) the possibility to avoid the use of toxic substances.

2. Material characteristics

The university of München and Fraunhofer have already performed basic tests to get an indication of material characteristics. According to the findings of Fraunhofer (2017) magnesite-bound typhate board has a low thermal conductivity of 0.052 W / mK. Typha board has an exceptionally high strength and dynamic stability and brings a number of additional positive properties:

- Renewable building material with very high mold resistance
- Good fire, sound and summer thermal protection
- Easy processability; with all common tools
- Relatively permeable to diffusion and capillary active
- Low energy consumption during production
- Traceability in the material cycle

The precise characteristics are still being studied. In Haus Kump sensors are integrated in the insulation to measure surface temperature, humidity, heat flow and above all the timberwork's moisture content. The results will lead to more detailed insights and recommendations for proper application.

3. Improving CO_2 footprints

The built environment is responsible for 45% of CO_2 emissions (EU 2015). Construction materials each have their own CO_2 footprint depending on how and where they are produced. This is no different for biobased products as Typha. For biological material it matters where the biomass is grown. The Netherlands are famous for their green peat-meadow landscapes with cows and windmills. To keep the feet of the cows and farmers dry drainage is essential. Unfortunately, this causes the peat lands to erode and emit CO_2. From research we know that this is quite substantial; "The total area of organic soils in agricultural use in the Netherlands in 2003 is, based on inventories, estimated at 223,000 ha. This area continues to decrease due to oxidation of shallow peat soils. The calculated annual emission of CO_2 amounts to 4.246 Mton CO_2 and for N_2O to 0.508 Mton CO_2 equivalents." (Verhagen e.o. 2009) Typha can be grown on land that is used for water storage necessary to buffer water of extreme weather events. From the feasibility study we know:

TABLE 2. TABLE CO_2 EMISSIONS PRODUCTION TYPHA

scenario	TYPHA PILOT PROJECTS		
	Density (m3/ha)	**CO_2 emission (kg/m3 material)**	**reduction CO_2 emission due to wetting (t CO_2/ha)**
Low intensive	58 m3 per ha	-185	8
Medium intensive	116 m3 per ha	-159	12

Two scenarios were calculated one low intensive (e.g. fields in Eastern Germany) and medium intensive (e.g. field in Friesland (NL)). Compared with stonewool, the low intensity scenario would emit 21.8t CO_2 e ha-1 yr-1 less and the medium intensive scenario would emit 40.7t CO_2 e ha-1 yr-1 less. CO_2 emission for energy needed for production of loose fill insulation was included, not the energy that is necessary for transport. Also the impact of the use of rest streams of Typha as substrate or pellets (Greifswald 2017) is not included. In order to keep the CO_2 emissions related to transport low, the feasibility study recommends short production, supply and recycle chains.

4. Compliance with the circular economy

The good fire behaviour (B1) (Fraunhofer 2018) and hydrophobic characteristics of Thypa create the opportunity to refrain from adding toxic additives. This will increase the chances for the successful reuse of the products after a first application. In the waste stages Typha will have a low environmental burden, due to the fact that it is an almost complete natural material that can easily be composted or burned. The product characteristics indicate that Typha is a sound alternative for fossil based insulation products.

Although there are quite some biobased alternatives available for the insulation of buildings we know from practice and desk research that it remains difficult to upscale their application. Recommendations from publications e.g. on circular use and new business models:

- The new business models require other roles for the stakeholders. Ownership is changing. Biobased materials and their supply-chains should match these concepts and use this change in ownership to their advantage and use Total Cost of Ownership.
- Procurement is important in the building sector. For an introduction of new materials is it essential that all technical information, environmental implications and juridical matters are transparent and available.
- Work with co-creation. In the new circular economy it is important to close the loop. Production, use and waste will involve many stakeholders.
- For the introduction of new materials it is important not to change everything at once, better small steps with smaller experiments than a complete make-over.
- Make sure that the tender process is focused on performance and not only on financial aspects. Tender with experts to build on their experience instead of starting with a lower price offer.

From studies towards other introductions of new biobased construction materials we know there are three key issues that should be tackled to ensure a proper introduction of a new (biobased) building material or product (e.g. De Mey e.o., 2015, van der Burgh e.o. 2016a, van der Burgh e.o. 2016b):

- Certification and proof of performance
- Availability of information necessary for proper application of the material and products
- Marketing, attractive packaging for contractors and applicators

5. THE RESULTS

Typha is in an early stage of development; there is no use of Typha in the building sector on a large scale yet. Pilots demonstrate that the Typha biomass can be used both as an insulation material, e.g. loose fill, and as construction board. Till now there are only some small pilots done, mainly in Germany. The technical properties seem very promising. The pilots also show that Typha is a material that is easy to handle and matches the expectation of contractors and applicators.

The overview made of the Life Cycle Inventory shows that there is not yet sufficient data available in the standard databases e.g. Ecoinvent and ELCD.

So far research related to Typha focuses mainly on restoration of peat lands, waste water treatment and the use of Typha for fuel. For the use of Typha as a construction material, like insulation or construction board, modelling of the whole process has started based upon some experiments done by Fraunhofer and Werner Thuerkorn.
Data about the agricultural production of the biomass and the processing from raw material to construction material are becoming available and can be used for a first assessment. A special point in the assessing of the environmental footprint is the iLUC. When natural peatland is transferred into agricultural peat land there will be effects on the carbon storage of the soil. This is a matter that has to be investigated. As the production of materials with Typha is a relatively simple process, the most environmental impacts will occur during the harvesting and transportation stages. Comparing with other insulation materials Typha has probably an advantage in the low input that is needed for the growth of the material, on the other hand the harvesting in wet conditions is more intensive than on dry land. Transport emissions can be diminished by choosing production and construction sites that are close to the fields where Typha is grown. The fact that Typha is a light-weight product is an advantage for transportation. The first LCA calculations show that with proper handling application of Typha has to potential to reduce the overall CO_2 footprint of the building or transformation project.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the results the conclusion can be drawn that Typha is a very promising newcomer in the construction industry. It provides the opportunity to contribute to reduce CO_2 emissions considerably and provides promising product characteristics in relation to the additional requirements made on building products in a circular economy.

More tests are necessary to back up the findings described and demonstrate the characteristics of the materials and products of Typha. It is recommended to focus on the most promising applications for insulation (loose fill) and construction board during the first stage. Pilots are also necessary to increase awareness of the possibilities in the different regional contexts of the Netherlands in the eyes of different stakeholders in the building sector, including the architects, purchasers, contractors and the permission giving bodies.

A pilot would also allow to fill in the blanks for a proper LCA. Data should be collected at the spot. Interesting could be to make a comparison between natural grown Typha versus agricultural grown Typha.

FURTHER READING

The reports of the feasibility study part of the InterReg VA project 'Bio-economie in the Non-Food sector' and other reports part on which this study was based.

REFERENCES

Burgh, van der G.F. & Verspeek E.F.L.M. (2016a), Bevordering opname van biobased bouwproducten in de Nationale Milieu Database (NMD), Green Deal Biobased Bouwen, Agrodome, Wageningen, Nederland.

Burgh, Fred van der & van de Linde, Jaap, (2016b), Eindrapportage Green Deal Biobased Bouwen, conclusies en aanbevelingen, RVO, Agrodome, Wageningen

Burgh, Fred van der & Verspeek, Sissy (2018), Making a *Circular biobased economy possible*, special reports Horizon 2020 Projects portal, http://www.horizon2020projects.com/special-reports/making-circular-biobased-economy-possible/ London UK, or https://www.agrodome.nl/wp-content/uploads/2018/08/2018-Horizon2020Projects-Making-circular-bio-based-economy-possible.pdf

De Mey, V., Verhoeven, J., Thoelen P., van Dam, J.E.G., Meyskens, S. & W. Schik (2015) 10 recommendations for stimulating biobased building materials, report Interreg IVB Grow2Build, 12th August 2015

EU (2015) Energy in Figures – Statistical Pocketbook 2015 edition, Brussels: European Commission.

Fraunhofer (2018) Technical factsheet Typhaboard

Fraunhofer (2017) Neuer tragfähiger und dämmender Baustoff aus rohrkolben (Typha), Product sheet IBP Fraunhofer

Fraunhofer (2011) Neuer Baustoff für umweltfreundliche und bautechnische Sanierung in der Denkmalpflege; Erprobung und wissenschaftliche Bewertung eines neuen Plattenmaterials im Rahmen eines Modellprojektes zur denkmalgerechten Sanierung eines mittelalterlichen Handwerkerhauses in der Nürnberger Altstadt, Förderprojekt der Deutschen Stiftung Umwelt AZ 27918

Greifswald (2017) Halmgutartige Festbrennstoffe aus nassen Mooren, Paludi-Pellets-Broschüre, https://www.moorwissen.de/doc/publikationen/paludi_pellets_broschuere/downloads/Dahms%20et%20al.%20(2017)%20Paludi-Pellets-Broschüre.pdf

Greifswald (2013) Peatlands – guidances for climate change mitiagation through conservations, rehabilitation and sustainable use, 2nd edition report authors Hans Joosten, Marja-Liisa Tapio-Biström & Susanna Tol (eds.) Published by the Food and Agriculture Organization of the United Nations and Wetlands International

Greifswald (2002) Wise use of mires and peatlands; backgrounds and principles including a framework for decision-making, authors: Hans Joosten & Donal Clarke, Published by: International Mire Conservation Group and International Peat Society.

Oostra, Mieke (2018) Typha feasibility study – recommendations for implementation in construction, InterReg VA project 'Bio-economie in the Non-Food sector'

Verhagen, A. e.o. (2009) Peatlands and carbon flows; outlook and importance for the Netherlands, Climate Change scientific assessment and policy analysis report WAB 500102 027, https://www.rivm.nl/bibliotheek/rapporten/500102027.pdf

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Quality Failures in Energy Saving Renovations of Residential Buildings in Northern China: A Case Study of Huhhot

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ABSTRACT

In order to reduce the energy consumption of existing buildings, the Chinese government has supported the energy-saving renovation of existing urban residential buildings since 2007. However, quality failures, which cannot meet government regulations, often occur during construction processes in energy saving renovation projects. The quality failure in construction projects is a common phenomenon throughout the world, and cause construction companies' rework, repair and other stakeholders' losses. Therefore, it is necessary to research quality failures in energy saving renovation projects of existing residential buildings in China. The research question of this article is: what are quality failures happening during construction processes in energy saving renovation projects? This study gives an overview of the renovation process and investigates the quality failures happens in the energy renovation projects in China.

Keywords: Quality failures; Energy saving renovations; Northern China

1. Introduction

The energy consumption of building sector accounts for a more significant proportion of the total energy consumption than both the industry and transportation. (Yang, L. et al., 2014). The magnitude of building energy consumption is rising rapidly year by year in China (Qian, Q. K. et al., 2012; Lin, B., Liu, H., 2015). In order to reduce energy-saving renovation led by the Chinese government has entered a large-scale implementation stage in northern China and a large number of existing buildings were renovated and are going to be renovated. However, quality failures, which cannot meet government regulations, are threats to construction projects success (Park, C. S., et al., 2013). Moreover, quality failures cause construction companies' rework, repair and other stakeholders' losses, and even poor construction performance and energy saving inefficiency.

There are various previous studies on identifying quality failures in construction projects. Chong, W. K. and Low, S. P. (2005) identified cracks, water seepage, delaminated tiles and other six types of quality failures based on construction elements and found the main quality failures with high frequency, including hollowness in tiles, rough finishing, chip offs, et al.

Georgiou, J., Love, P. E. D., and Smith, J. (1999) came up with 12 types of quality failures, like external leaks, incomplete, internal leaks, miscellaneous et al. In addition, Georgiou, J. (2010) refined and analyzed the various defects to find the major quality failures, like no head flashing provided to external architrave over near window. Forcada, N., Macarulla, M., and Love, P. E. (2012) tried to reveal the most common defects, including incomplete tile grouting and incorrect fixtures and fittings in toilets and failure to apply second coats of paint to walls. In China, hollowing, deflection, cracks and other quality failures in energy saving renovation projects are also identified (Jiuwang Chen et al., 2016; Xixi Liu, 2015).

However, there is a lack of quality failures framework and in-depth analysis in energy saving renovation projects in Northern China. This study aims to establish the quality failures framework according to the renovation process based on literature review globally and try to apply the framework to investigate the quality failure in the Chinese context, based on a case study of energy saving renovation projects in Huhhot, Northeast of Mainland China.

2. Methodology

2.1 Literature review

The public parties set the regulatory framework to assure energy-saving construction quality in existing residential buildings. The regulatory rules give descriptions to quality requirements and mandatory construction procedures.

--Code for acceptance of energy efficient building construction (GB 50411-2007)

--Standard for energy efficiency test of residential buildings (JGJ/T 132-2009)

--Acceptance measures for heating meter and energy saving renovation projects of existing residential buildings in northern heating areas (Ministry of housing and urban-rural development of the People's Republic of China, 2009)

--Technical guidelines for heat supply meter and energy-saving renovation of existing residential buildings in northern heating areas (Ministry of housing and urban-rural development of the People's Republic of China, 2008)

2.2 Expert interview

The expert interview is a vital method to collect data in this study. There are 22 experts including the main stakeholders in energy saving renovation projects, including government, construction companies, and supervision companies. Among all the interviewees，11 are project managers, 4 are supervisors, two designers and 5 are government officials. In order to make the quality failures identified complete and reliable, 22 experts were asked to confirm the renovation process provided by the chart prepared by the author. They were asked then to identify the quality failures according to each stage of renovation processes charts and offering reference to the construction reports and documents from quality control processes.

The cases selected in this study is in Huhhot, a typical northern city in China. The energy-saving renovation of existing buildings started in Hohhot since 2008, and the policies and regulations of energy-saving renovations issued by the central government are applied. It is a typical city of the whole heating areas in northern China in energy saving renovation context.

In particular, 16 of the 22 experts are involved in 5 energy saving renovation projects of existing residential buildings to participate in the whole construction processes. These 5 cases are all located in the urban area of Hohhot. From energy-saving renovation technologies' perspective, all cases are by the technical requirements of the national energy-saving renovation regulations for existing residential buildings.

3. Data results and conclusion

In this study, regulations on construction quality in energy saving renovation projects were studied and combined with the results of expert interviews. There are results as shown following.

1) The construction processes divided into three technological measurement categories, including door and window, roof and external wall.

2) Based on three categories of technology measurements, the quality failures appearing will be found out by expert interview. In three technical categories, a total of 25 quality failures are identified, of which four quality failures are for doors and windows, nine quality failures are for the roof, and 12 quality failures are for external walls.

3) With comparing the 25 quality failures with the quality failures identified in the literature, similar quality failures are found such as incorrect fixtures, which means that the similar quality failures may occur in the international construction projects in general. On the other hand, several quality failures differ from quality failures identified in the literature, such as incongruous the size of the new window frame and door frame, which is determined by the technological measurement and construction procedures for building energy efficiency renovation projects in the Chinese context.

REFERENCES

Jiuwang Chen, Youqing Wang 2016. Both the quality control of the residential building energy-saving rebuilding project. The construction of science and Technology (9), 42-45. (in Chinese)

Lin, B., & Liu, H. 2015. China's building energy efficiency and urbanization. Energy and Buildings, 86, 356-365.

Liu Xixi 2015 discussion on common quality problems in existing energy-saving buildings. Shanxi architecture, 41 (21), 165-166. (in Chinese)

Qian, Q. K., Chan, E. H., & Choy, L. H. 2012. REAL ESTATE DEVELOPERS'CONCERNS ABOUT UNCERTAINTY IN BUILDING ENERGY EFFICIENCY (BEE) INVESTMENT—A TRANSACTION COSTS (TCS) PERSPECTIVE. Journal of Green Building, 7(4), 116-129.

Yang, L., Yan, H., & Lam, J. C. 2014. Thermal comfort and building energy consumption implications–a review. Applied Energy, 115, 164-173.

Park, C. S., Lee, D. Y., Kwon, O. S., & Wang, X. 2013. A framework for proactive construction defect management using BIM, augmented reality and ontology-based data collection template. Automation in Construction, 33, 61-71.

Chong, W. K., & Low, S. P. 2005. Assessment of defects at construction and occupancy stages. Journal of Performance of Constructed facilities, 19(4), 283-289.

Georgiou, J., Love, P. E. D., & Smith, J. 1999. A comparison of defects in houses constructed by owners and registered builders in the Australian State of Victoria. Structural Survey, 17(3), 160-169.

Georgiou, J. 2010. Verification of a building defect classification system for housing. Structural Survey, 28(5), 370-383.

Acceptance measures for heating meter and energy saving renovation projects of existing residential buildings in northern heating areas (Ministry of housing and urban rural development of the People's Republic of China, 2009) (in Chinese).

Technical guidelines for heat supply meter and energy saving renovation of existing residential buildings in northern heating areas (Ministry of housing and urban rural development of the People's Republic of China, 2008) (in Chinese).

Code for acceptance of energy efficient building construction, 2007, the State Council of the People's Republic of China (GB 50411-2007) (in Chinese).

The standard for energy efficiency test of residential buildings, 2009, the State Council of the People's Republic of China (in Chinese).

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Effects of Fabric Retrofit Insulation on Temperature Take-Back

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ABSTRACT

This paper presents a two-year-long empirical study on the effects of fabric retrofit insulation on temperature take-back in a high-rise social-housing building (23-storey block) in Newcastle upon Tyne (UK). The study has followed a quasi-experimental approach coupled with qualitative methods and examines whether temperature take-back has taking place; the saturation effect and the relationship between temperature take-back, physical factors and occupant's behavioural change. First, the evidence suggests that temperature take-back is not occurring and instead the saturation effect has taken place. Second, a maximum take-back temperature was achieved ranging from 20.85°C-24.81°C. The study also suggests that to evaluate appropriateness of retrofitted insulation measures, pre-intervention variables such as internal temperatures, heating system and building fabric performance should be taken into account.

Keywords: Energy, retrofit, temperature take-back.

1. INTRODUCTION

This empirical study stemmed from a query raised by a social housing provider to better understand the effects of building fabric retrofit on a deprived area.It is known that domestic energy demand is affected by factors which are complex and often poorly understood (Oreszczyn & Lowe, 2010), especially in social homes, in which energy demand could be far from energy models (Teli et al, 2016). Empirical information on temperatures in domestic dwellings is valuable in appraising energy conservation interventions as, for example, the benefits of an energy efficiency intervention can be taken as extra warmth and the reduction in energy consumption saving associated with that change (Milne & Boardman, 2000; Poortinga et al, 2018; Sorrell, 2007). This is known as temperature take-back (TTB).Previous studies have shown that: TTB ranged from 0.14°C to 1.6°C (Sorrell et al, 2009), 1°C rise in internal temperature increases the space heating consumption by 10% or more (Sorrell, 2007) and up to 100% of energy savings is lost through TTB with a mean around 20% (Sorrell et al, 2009). TTB is higher in low-income householders (Milne & Boardman, 2000; Sorrell, 2007) one suggested reason is that financial constraints would lead to very low pre-intervention temperatures (Milne & Boardman, 2000). TTB may also decrease owing to saturation effects when pre-intervention internal temperatures saturate (reaching 21°C)(Sorrell, 2007). This has been conceptualised as the saturation effect: the reduction in the level of service required (e.g. internal temperature) as the gap between that required service and thermal comfort level is reduced. Research studies have also theorised that half of the TTB is accounted by the physical factors[1] and the remainder by the occupant's behavioural change (Oreszczyn et al, 2006; Sanders & Phillipson, 2006; Sorrell, 2007).

Building upon previous research propositions and findings, this investigation primary research proposition is that TTB exists and can be observed. Thus, on a UK high-rise social housing building, this paper interrogates: whether TTB has taking place; the saturation effect; and the relationship between TTB, physical factors and occupant's behavioural change.

2. METHODOLOGY

This study has followed the so called physical paradigm approach, unlike the engineering approach, it is not based on theoretical models for estimating potential savings but on physical monitoring before and after building retrofit and does not predetermine occupant practices. In a fabric retrofit context, energy-efficiency intervention effects on energy demand can be determined measuring the change in energy service or energy input (Sorrell et al, 2009). Moreover, internal temperature is the preferred energy service demand variable to be observed (Love, 2014) and taken as a pathway towards measuring temperature take-back in retrofit insulation studies (Oreszczyn et al, 2006). This has been termed 'quasi-experimental' (Sorrell et al, 2009). This study has followed a quasi-experimental approach coupled with qualitative methods and follow a convergent research design rationale so that a more complete understanding of the phenomena emerges (Doyle et al, 2016).The applied quasi-experimental approach measures the change in internal air temperature (energy service) and space heating consumption (energy input) before and after retrofit in two high-rise social-housing buildings in Newcastle upon Tyne, UK: CPH as the target building, and The Hawthorns as the control building. The target building is a 23-storey block with 157 flats and underwent retrofit insulation (solid external wall insulation and double glazing windows) from September 2014 to February 2015 .

3. RESULTS AND DISCUSSION

Fig. 1 shows an increase in mean internal air temperatures (MIAT) of +0.46° (from 22.07°C-22.53°C) and Table 1 shows that the change in weather-normalised space-heating consumption following retrofit for the target building was −27% with a potential relative difference between target and control group of −34%. Thus, if only overall temperature figures are taken into account, it could be inferred that TTB has taken place as there is an increase in MIATfollowing the building fabric retrofit and the reduction in energy consumption saving associated with that change. In low-income households, in theory, this increase in temperature is likely due to an unmet demand for energy services, such as warmth, which needs to be satisfied. However, the results in the form of individual flat and qualitative data shows that the increase in MIAT is not homogeneous. Moreover, in terms of space heating consumption, less than half of the individual dwellings are experiencing a reduction of space heating consumption post-retrofit. Furthermore, the internal threshold temperature of recommended temperature for healthy environments (DCLG, 2006) (21.0°C in living rooms (WHO, 1987)) was achieved before retrofit (22.07°C) and the fabric efficiency upgrade increased the internal air temperature beyond that recommended threshold (22.53°C). In addition, there is a negligible decrease in energy saving when compared to average national consumption (DECC, 2013). Therefore, this paper argues that the saturation effect has taken place as suggested by Sorrell (2007). That is,temperature take-back decreases owing to saturation effects when pre-intervention internal temperatures saturate (approaching 21°C) (Sorrell, 2007). This implies that adding more energy efficiency measures (e.g. wall insulation, double glazing) to a household physical and heating system where indoor

[1] e.g. building fabric retrofitted insulation and heating systems

temperatures approach the maximum level for thermal comfort will yield a negligible decrease in energy saving consumption in absolute terms.

The empirical evidence also indicates that a maximum take-back temperature was achieved for the dwellings ranging from 20.85°C to 24.81°C.In addition there is a quasi-flat internal air temperature profile and small maximum temperature differences pre-and post-retrofit. A flat internal temperature profile may denote the absence of occupant-controlled heating periods, and heating period length changes as defined by the BREDEM-12 heating profile (Anderson et al, 2002). Consequently, this absence of pre- and post-retrofit heating periods suggest that the increase of standardised MIAT following the upgrade (+0.46°C) may be the result of unheated periods and it appears to be more related to building-related physical processes rather than switching the heating on by occupants (occupant behaviour).

4. CONCLUSION

The evidence presented in this paper is based on one specific, detailed, and contextualised case. The presented results suggest that, first, temperature take-back as extra warmth (or energy consumption savings) has not taken place. Second, an unintended saturation effect has taken place. This supports the assumption that temperature take-back decreases owing to saturation effects when pre-intervention internal temperatures saturate (approaching 21°C) in lieu of the hypothesis that low-income householders take the benefits of an energy efficiency intervention as extra-warmth rather than energy savings. Third, a maximum take-back temperature was achieved for the dwellings ranging from 20.85°C to 24.81°C. Fourth, heating behavioural factors appear to be less relevant than energy-efficiency improvements to explain the increased of standardised mean internal air temperature. However, it is unclear how much behavioural factors account for this and further research would be needed. The study also suggests that if these results were more broadly confirmed, future local guidelines to evaluate appropriateness of energy-efficiency interventions should take into account pre-intervention variables such as internal temperatures, heating system and building fabric performance, in order to suggest the best energy efficiency measure.

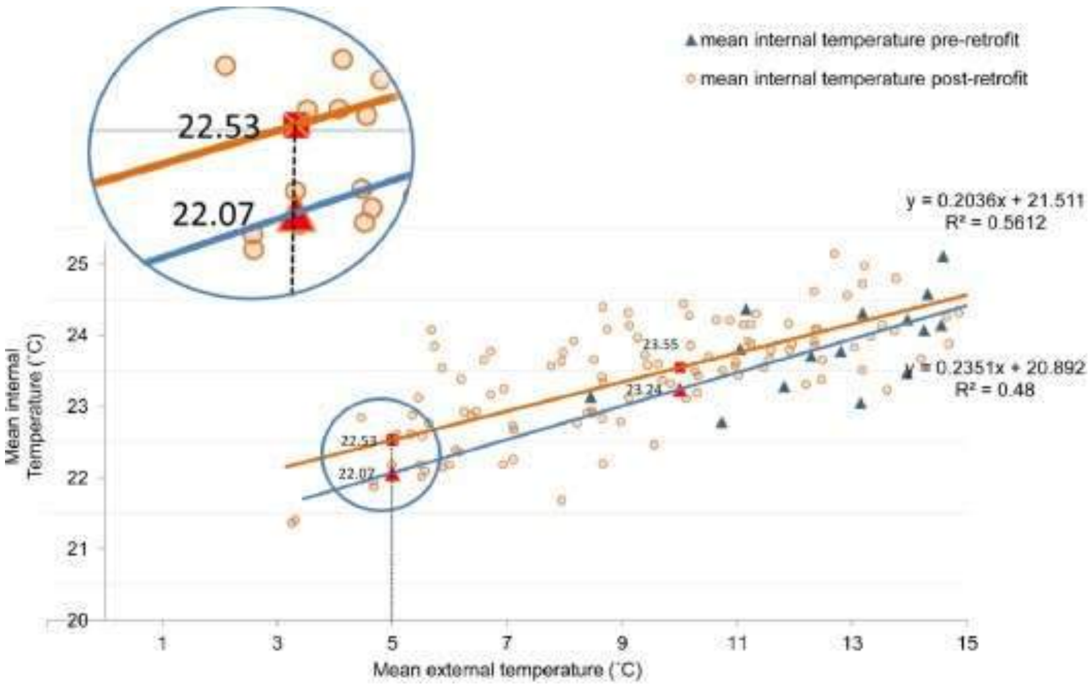

Fig. 1. Standardised mean internal air temperature of the target building, at 5.0 °C external temperature. Pre- and post-retrofit (n = 9).

Retrofit Status	Weather normalised space heating consumption percentage change		
	Target building ($WhK^{-1} m^{-2} d^{-1}$)	Control building ($WhK^{-1} m^{-2} d^{-1}$)	$\Delta(Target - Control)$ building(%)
Pre-retrofit	0.0184	0.0460	
Post-retrofit	0.0134	0.0494	
$\Delta(Pre - Post)$retrofit (%)	−27	7	−34

Table 1.Weather normalised space heating consumption percentage change in target building, control building, and relative to each other.

FURTHER READING

This paper is based on the following publication:

Effects of fabric retrofit insulation in a UK high-rise social housing building on temperature take-back.

https://www.sciencedirect.com/science/article/pii/S037877881734094X

REFERENCES

Anderson, B. R., Chapman, P. F., Cutland, N. G., Dickson, C. M., Doran, S. M., Henderson, G., Henderson, J. H., Iles, P. J., Kosmina, L. & Shorrock, L. D. (2002) *BREDEM-12 Model description: 2001 update*.Garston, Watford, UK.

DCLG (2006) *Housing health and safety rating system- guidance for landlords and property related professionals.* London: Department for Communities and Local Government.

DECC (2013) *The Future of Heating: Meeting the challenge.* London: Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf [Accessed

Doyle, L., Brady, A.-M. & Byrne, G. (2016) An overview of mixed methods research–revisited. *Journal of research in nursing*, 21(8), 623-635.

Love, J. (2014) *Understanding the interactions between occupants, heating systems and building fabricin the context of energy efficient building fabric retrofit in social housing*Ph.D. thesis. UCL.

Milne, G. & Boardman, B. (2000) Making cold homes warmer: the effect of energy efficiency improvements in low-income homes A report to the Energy Action Grants Agency Charitable Trust. *Energy Policy*, 28(6), 411-424.

Oreszczyn, T., Hong, S. H., Ridley, I. & Wilkinson, P. (2006) Determinants of winter indoor temperatures in low income households in England. *Energy and Buildings*, 38(3), 245-252.

Oreszczyn, T. & Lowe, R. (2010) Challenges for energy and buildings research: objectives, methods and funding mechanisms. *Building Research & Information*, 38(1), 107-122.

Poortinga, W., Jiang, S., Grey, C. & Tweed, C. (2018) Impacts of energy-efficiency investments on internal conditions in low-income households. *Building Research & Information*, 46(6), 653-667.

Sanders, C. & Phillipson, M. (2006) *An Analysis of the Difference between Measured and Predicted Energy Savings when Houses are Insulated* Centre for Research on Indoor Climate and Health, Glasgow Caledonian University; 2006., University;, G. C.

Sorrell, S. (2007) *The Rebound Effect: An Assessment of the Evidence for Economy-wide Energy Savings from Improved Energy Efficiency*.

Sorrell, S., Dimitropoulos, J. & Sommerville, M. (2009) Empirical estimates of the direct rebound effect: A review. *Energy Policy*, 37(4), 1356-1371.

Teli, D., Dimitriou, T., James, P., Bahaj, A., Ellison, L. & Waggott, A. (2016) Fuel poverty-induced 'prebound effect' in achieving the anticipated carbon savings from social housing retrofit. *Building Services Engineering Research and Technology*, 37(2), 176-193.

WHO (1987) *Health Impact of Low Temperatures*.Copenhagen.

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Refurbishing Construction Material Depots facilitate Dutch Retrofit Housing

Post PhD Research on Circular Occupied-housing matching the Material Depot Market.

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ABSTRACT

For speeding-up the retrofit[1] use of demolished construction materials in new housing instead of focusing on the re-use of new materials at the end of the housing lifecycle, former research led to the conclusion that in the Dutch situation material depots that refurbish[2] construction materials are needed. Only then occupied-housing costumers can and will invest in such housing. Refurbishing is needed for uplifting the lifespan of demolished construction materials to the level of new materials for mixed use coupled to insurance conditions. Unless the first pilot development project like KOMST on the Zeeburger' Island in Amsterdam have been started-up, the development of 'Material depots' is behind in development. This can lead to a huge delay in circular occupied-housing development. That's why research is done visiting and interviewing the management of the five still remaining construction material depot locations in the Netherlands, to explore consumer-oriented growth conditions.

Keywords: circular housing, refurbished-construction-materials, occupied-housing-matching

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1. THE CIRCULAR CHALLENGE OF RETROFIT OCCUPIED HOUSING

Circular building leads to a different way of thinking and building. BPD development is experimenting with 19 owner-occupied houses on the Amsterdam Zeeburger Island in the Netherlands, to use as many refurbished materials in cooperation with the coming housing owners, so far these are available at the existing materials depots. It is a pilot project because household's consumers do not know the possibilities sufficiently and do not yet expect refurbishes material options from a developer. It is interesting how consumer-housing buyers deal with this offer and what we can learn from this to stimulate this development nationwide [Post PhD dissertation added research results].

The current practice of circular construction mainly focuses on the demountable construction of new buildings, that demolishing materials at the end of life cycle materials can be reused. This approach of buildings consisting of dismountable parts though takes advantage of the building technique of the sixties of the last century, dominated by the ideas of John Ha-

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[1] Retrofit, the definition for housing is development is the re-use of demolished materials in new housing and by renovation of housing.
[2] Refurbish, the definition for housing developments is the upgrading of demolished materials for re-use in housing building activities.

braken (Habraken, 1961). The demountable option implicitly positively created the option that new buildings from now on become to be built from sustainable materials, what can be stimulated by allowing suppliers to be and remain the materials owner, coupled with lease constructions as introduced by the architect Thomas Rau (Rau and Oberhuber, 2017). Quality certificates such as Breeam are linked to this approach. The approach has a direct influence on the selection of materials for construction and thus stimulates sustainable materials development. However, the circular re-use of building materials, other than with the use of refurbished building materials (Lansink and De Vries-in't Veld, 2010) will only take place in the final demolition, as can be expected over 50 to 200 years from now on.

The first development for retrofit residential construction mainly took place in the rental sector, due to the re-characterizing nature of most of the social housing stock. For the coming years, its the expected development that most of the new housing developments will be built as occupied-housing, because the consumer demand for occupied housing is high and the construction by social housing corporations has fallen sharply due to lack on investment potential. For the climate-change transition, it is important that circularity is introduced into new occupied housing on short notice. Every year in the Netherlands, an average of 15,000 dwellings are demolished, what should make it practically possible to re-use building materials 'refurbished' on large scale. Assuming a new construction of 60,000 to 80,000 homes on an annual basis and 60% reusability of building material from demolished homes, this involves the capacity of approximately 20% reuse at home level.

2. MATCHING CONSUMERS WITH RETROFIT OCCUPIED HOUSING

For a breakthrough in the use of 'refurbished' building materials in the construction of new homes, it is necessary that the circular match between housing consumers and new housing developments will be made, logically taking into account the wishes of the housing buyers, future use and developments in construction technology. For housing buyers this means more than making choices out of the total offering of new to be built houses. The choice for a 'refurbished' circular home must fit their personal lifestyle and that begins with the potentials of the construction material depots. That is the result of interviewing stakeholders and participants of this KOMST BPD new to build refurbished housing development.

To make clear the function and possibilities of these construction material depots for facilitating the match between housing consumers and retrofit new housing developments, a post-PhD research on the remaining Dutch construction material depot locations is in process.

The central research question is:

‘How can construction material depots facilitate prosperity in the development and sale of new retrofit occupied housing?’

To find answers the following steps are operated: 1. Sketching the urgency for new retrofit occupied housing matching consumers wishes, 2. Interviewing the managers of the remaining Dutch construction material depots how they see possible developments, and 3. Analysis the results for answering the research question, what will be delivered special for the SBE19 Eindhoven conference on retrofit market oriented innovation for making the building environment sustainable according to UN Paris agreement (UN, 2015).

By making a combination of my PhD dissertation results (Sanders, 2014) and post-PhD added research on civilian responsibility for sustainable housing and resident initiative included sustainable investments (Sanders and Van Timmeren, 2018), completed with a sketch of the depots urgency [chapter 3], a depot inventory [chapter 4] and interviewing market demand key persons [chapter 5], the research question is answered by matching these, creating conclusions and giving remarks to these [chapter 6].

3. THE URGENCY FOR DUTCH CONSTRUCTION MATERIAL DEPOTS

For a breakthrough in the use of 'refurbished' building materials in the construction of new homes, it is necessary that the circular match between housing consumers and new housing developments will be made, logically taking into account the wishes of the housing buyers, future use and developments in construction technology. For housing buyers this means more than making choices out of the total offering of new to be built houses. The choice for a 'refurbished' circular home must fit their personal lifestyle.

The range of 'refurbished' new homes however is minimally, probable because this kind of housing is new to consumers and developers, and most of municipalities avoid every potential risk of delays in their building production. The active collection of demolished building materials on a large scale is therefore also postponed. In recent years, many existing depots have been closed due to a lack of interest. With this, the essential opportunity to give circular construction a boost in the short term is shifted to the future. Not only the rental sector, but also the owner-occupied sector is acting insufficiently in this.

Professionals and consumers therefore have to build up experience and teach municipalities how to give the right environmental conditions. Consumers act on a much smaller scale and with a shorter time horizon than professionals. The buyer of a new-build home first of all cares about his own home and its affordability, while the professionals of both developers and municipalities are mainly concerned with the overall housing production task. These two worlds can only 'match' if both 'camps' move into each other's perception. The consumer must understand that within a development there is always a limited choice because a developer must achieve a cost-efficiency and qualitative result. The professional must realize that every individually sold sustainable home must contribute to better housing stock over time. Being the conclusions of my PhD dissertation and added post-PhD research.

For a breakthrough in retrofit building on the short-term, for expanding the use of demolished construction materials in new housing instead of focusing on the re-use of new materials at the end of the housing lifecycle, the mentioned former research led to the conclusion that in the Dutch situation material depots that refurbish construction materials are needed. Only then occupied-housing costumers can and will invest in such housing. Refurbishing is needed for uplifting the lifespan of demolished construction materials to the level of new materials for mixed use coupled to insurance conditions.

4. DUTCH CONSTRUCTION MATERIAL DEPOTS INVENTORY

Unless the first pilot development project like KOMST on the Zeeburger' Island in Amsterdam have been started-up, the development of ‘Material depots’ is behind in development, there are only fifteen depot locations left. This can lead to a huge delay in retrofit occupied-housing development. That’s why research is done visiting and interviewing the management of these still remaining construction material depot locations in the Netherlands, to explore consumer-oriented growth conditions.

That’s why first an inventory on construction material depots in the Netherlands is done, and one of them is visited and interviewed during spring 2018 [4.A]. Additional the project-leader of the KOMST project is interviewed, for an impression on the purchase question on behalves of the housing buyers according to used and refurbished construction materials [4.B]. The construction depots inventory gave an impression how these could answer to this purchase question. That two research components offer the ingredients to answer the research question [chapter 2] qualitatively. Secondly for the two Dutch cities Amersfoort and Utrecht an inventory of construction material flows is analysed [4.C], to add to these qualitative results a quantitative picture to interpolate this to the Dutch countrywide scale. Research done; to explore the need for construction material depots in the Netherlands.

A; Inventory of construction depots
Based on Google scanning the number of construction material depots is counted on 18 locations differing to purpose and size. Most depots are situated in the western part of the country where the most people live and where therewith the most houses and buildings are situated. From these 18 depots; 3 are in the southern part and one in the eastern part of the country, the other 14 are in de western delta region located. Although the difference of scope do not differ much, there are difference in between these construction material depots; 4 of these focus on vintage material [like greenhouse parts and stained glass for instance], 5 depots focus on windows and doors [front-doors and indoor-doors], and the other 9 present a variety of construction materials, from wood material mainly. All of these depots focus on construction materials from demolished houses although some of them accept material from old buildings too, from classic small offices and extraordinary buildings mainly. There sizes differ enormously; only four of all these depots really have size that they have indoor and outdoor storage, 1 to 2 acres of scale. From interviewing the oldest 'Eemnes' location it became clear that most of the materials arriving from demolishing activities, have to be refurbished before they can be sold for reuse, see figure 1. Brick stones and roof tiles have to be cleaned up and stripped of cement layers. Parts from wood like old doors and windows have te be repaired and painted mainly, and most of the doors to be sold are made new from wood parts to meet construction standards. This because insurance certificates are coupled to these standard, as they have to be delivered by housing developers in general.

Figure 1, Impression of the Eemnes construction material depot.

B; Interviewing KOMST project-leader
Interviewing the commercial project-leader of the KOMST project, made clear that the housing buying household people have chosen positive motivated to join the project, see figure 2. By introducing old materials, classic parts and refurbished materials, their houses to be built will gain attraction, ambiance and financial value, to their opinion. For buying these parts they got vouchers from their housing developer. To explain, from the money they bought the house they got a 5% back in vouchers for buying these demolished materials. Therewith they did not built their houses from demolished materials; they decorated their house with it. The main parts they used were old classic kitchens, windows with old glass and classic front doors. The houses of the KOMST project are high value houses, with prizes three time average household houses. To explain a little, the easiness of the participants to invest themselves in vouchers and the relatively low percentage of the used demolished materials, the 5% mentioned. It also explains that the architect could effort the time for accompanying the participating housing buyers to select materials and reshape the design to these. The households were not interested in old materials in general like bricks and roof tiles, they chose for the old materials alone for creating aesthetic and financial value, and felt obstructed because of construction quality. KOMST in the Netherlands is the one of the first projects that reached that stage of development. Conclusions from the project cannot easily be interpolated to other projects, because of the expensive level of the houses, and the small number of houses in the project. What can be said though, is that the architect addressed that the lack of certificates on most of the refurbished construction materials blocks the use for constructive housing details.

Figure 2, Impression of the KOMST project Zeeburgereiland Amsterdam.

C; Analysing 'Urban mining' Amersfoort and Utrecht
Based on reports of the Metabolic consultancy [Amersfoort 2017 and Utrecht 2017] for these cities an approach for the construction material waste flows of Dutch cities is worked out. For these two cities Amersfoort [155.000 citizens] and Utrecht [345.000 citizens] the expected construction material production and actual use respectively are 12.500/125.000 ton/ton [10%] and 65.000/1.250.000 ton/ton [5%] whereby the re-use consists of 60% concrete, 15% sand, 15% stone, and 10% glass related material. Based on the Amersfoort situation the expected results of local urban mining management are that 25% of the construction material use could be brought-up out of the local waste production; 25% instead of the actual 10% [2,5 times more] and the re-use of construction waste can be increased to 60% of the total construction waste disposal production; 60% instead of 5% [12 times more]. The re-use of wood materials thereby to a large extent does make the difference, because used wood materials in the actual Dutch situation is used for electric production, a low quality re-use approach. With the knowledge that 60% of the 17,5 million Dutch people live in cities, larger and smaller cities above 50.000 citizens a city, the construction waste picture for the country can approximately be made by multiplying the summation of these numbers with a factor 20.

5. MATCHING MARKET DEMANDS AND DEPOTS FACILITIES

The re-use of construction materials in new housing developments as can be concluded; seems to be in an impasse in between good construction prospects for the re-use of used natural or refurbished materials in new housing developments; 12 times more then the actual practise in the Netherlands, if buyers and their developers become willing to embrace its vintage appearance, accept another certificate quality, and if the urban-mining process becomes facilitated by more and more focused construction material depots.

From analysing the 'Urban Mining' potential it becomes clear, that; 1. The potential quantity is more then ten times the actual practise results, 2. The participating potential of household searching for occupied housing is little known and researched, and 3. The available construction material depots are far to less in number, in quantity and not coupled to the cities to handle the potential demand if this develops in time. Some remarks to these conclusions should be made:

D; The quantitative effect of more re-use of construction materials from demolishing of houses and other buildings, show to depend on the quality of the materials that can be delivered to the housing buyers and their developers, and there-to related the quality of refurbishing the demolished materials, and the possibilities to get these material certificates for the contractors because of insurance factors. What makes it important that the depots have the utilities and people with the skills, for cleaning-up the materials and refurbish these if needed.

E; More knowledge is needed about household preferences according to the use of more then the actual percentages of demolished construction materials, refurbished or not, in new housing developments. Therewith the attitude and behaviour of housing developers and contractors, and the policies of government like municipalities, have to become clearer for such situations. As there is known that the more urgent climate-change targets become, the less governmental officials take into account the people involved (Sanders, 2014), its becomes urgent to research this mutual behaviour for implementation, see figure 3.

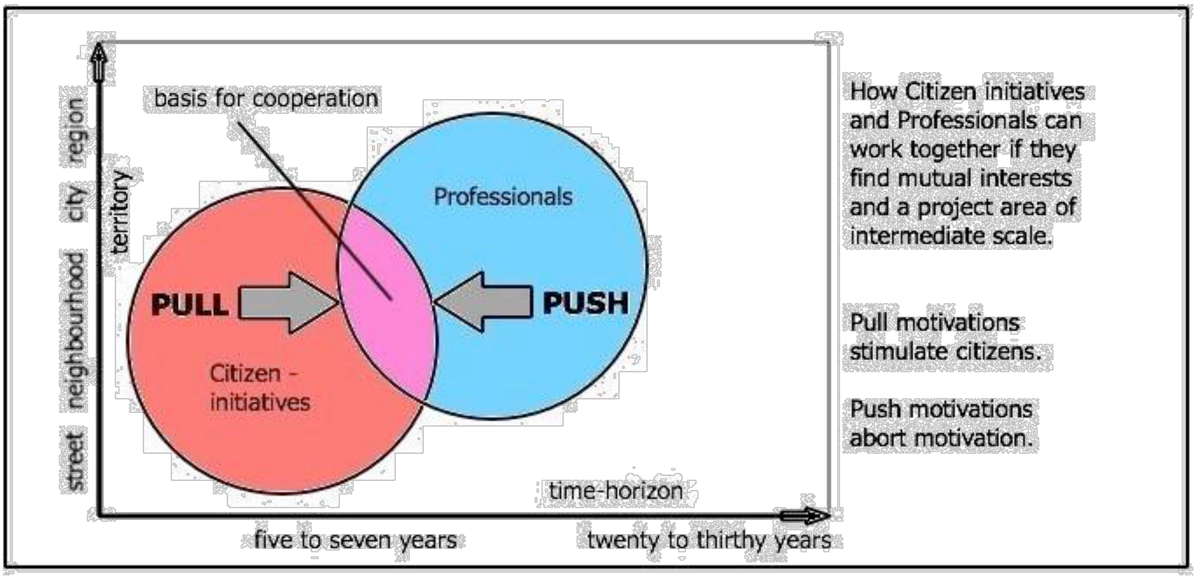

Figure 3, Diagram on the overlap productivity of civilians and professionals (Sanders, 2014)

F; The whole development of urban mining concerning housing construction materials depends on the start-up and setup of such depots near or in cities. Logically this should be started in the cities with the biggest plans for new housing developments, where the municipalities are willing to support and possibly subsidize the depot developments. Such depots has to be far more larger then the actual existing depots, what makes it uncertain whether the existing and new entrepreneurs will take the initiative to step in these new type depot developments. It's therefor recommended to study the operational and financial business-cases for these new-type construction material depots.

G; With the knowledge that 30% of the housing development CO_2 emission is caused by transportation activities (Bijleveld et al., 2015), additionally these depots should be created with the cities managing local closed waste cycles, to reduce mobility flows to the minimum.

6. REMARKS AND THOUGHTS

The content of this research on construction material depots, the introduction and the research results A, B and C, helped to formulate the conclusions D, E, F and G to give the development of these depots a direction by answering the research question of chapter 2. New questions therewith arose, questions for further research and open questions to entrepreneurs and professionals as from municipalities, to consider by them the possible negative influences to overcome for prosperous development of construction material depots. Therewith the research done should be seen as research of exploring attitude, for clearing-up the situation by making a first inventory of the questions for all participants of the playing filed. This all for giving an scientific support for making occupied housing developments circular.

REFERENCES

BIJLEVELD, M., BERGSMA, G., KRUTWAGEN, B. & AFMAN, M. 2015. Measuring is knowing [Dutch: 'Meten is weten'] Emiission impacts of the Dutch construction and demolishing workflows in 2010. Delft: CE Delft.

HABRAKEN, N. 1961. *De dragers en de mensen: Het einde van de massawoningbouw*, Scheltema & Holkema.

LANSINK, A. & DE VRIES-IN'T VELD, H. 2010. *The power of recycling (Dutch: De kracht van de Kringloop: geschiedenis en toekomst van de Ladder van Lansink).*

RAU, T. & OBERHUBER, S. 2017. Material matters, het alternatief voor onze roofbouwmaatschappij, Bertram en de Leeuw Uitgevers. ISBN.

SANDERS, F. C. 2014. *Sustainable Development through Resident's Collective Initiatives (Dutch: Duurzame ontwikkeling door collectief bewonersinitiatief, leidraad voor professionals om bewonersgroepen aan de duurzaamheidsopgave te verbinden) (Peer-reviewed Dissertation),* Delft, Delft University of Technology.

SANDERS, F. C. & VAN TIMMEREN, A. 2018. 'Circular cities by the energy of people', Post PhD best practices research on Amsterdam and Rotterdam citizen initiatives. *Constructing an Urban Future.* Abu Dhabi University (UAE).

UN 2015. Paris Agreements framework convention on climate change. *Paris, France.*

Scientific biography author

The behaviour of citizens related to climate change and sustainable responsibility has always been my concern. The questions are how can citizens overcome the social stress of cities, help each other to take advancement of labour opportunities, how can they give foundation for sustainable cities and seek societal responsibility. That drives me into research, into workshops and lectures to involve others into this important topic of civilian initiative and sustainability nowadays. My interest has grown during my working carrier as an Urbanist in sustainable city development for government and a social housing company, before I was asked for my PhD at the architecture department at Delft University of Technology. My MBA and post MBA years studying at the Dutch Erasmus University and IMD Lausanne helped me to learn how to reach targets with others. That helped to become me the messenger and researcher that I am today, by publishing on the new topics of citizen responsibility, circularity, resilience concerning the building environment related to the mobilization of citizens. What gives me the opportunity to visit universities in Europe, the Russian hemisphere as in Asia, for stimulating the energy transition in the built environment globally.

Education

- 2009 to 2014: PhD at Delft University of Technology; on citizen initiative [Sept. 2014].
- 2003 to 2007: IMD Lausanne, High Performance Leadership and Winning Performance
- 1991 to 1993: NOVAM, financial program real-estate developments.
- 1985 to 1986: MBA at Erasmus University at Rotterdam; organizational development.
- 1974 to 1982: Civil & Coastal Engineering Delft University of Technology.

Scientific working experience

- In 2016: Lecturer Building Environment, at The Hague University of Applied Science.
- From 2014 on: Ambassador 'Citizens Initiative', Urbanism, Delft Un. Of technology.
- 2014 to 2015: Senior Lecturer at TSM Business School, Twente Un. of Technology.
- 2008 to 2014: PhD at Urbanism Prof. dr. A. van Timmeren, Delft University of Technology.

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Retrofitting building stocks – the perspectives of material flows and circular economy

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ABSTRACT

Changing natural and social conditions require an adaptation of the European building stock. A goal with increasing attention is the conservation of materials. The key question is how to strengthen circular economy with regard to building materials. So far, a lot of knowledge is already being gathered concerning the material stock of the built environment, but without considering the specific requirements of actors adequately who are involved in decision making and influence the respective material flows. This paper aims on introducing theses in order to point out key aspects of the need for action and research for retrofitting processes with regard to the building stock, based on existing experience and previous work related to material flows in the built environment.

Keywords: retrofitting building material stock; circular economy; need for action

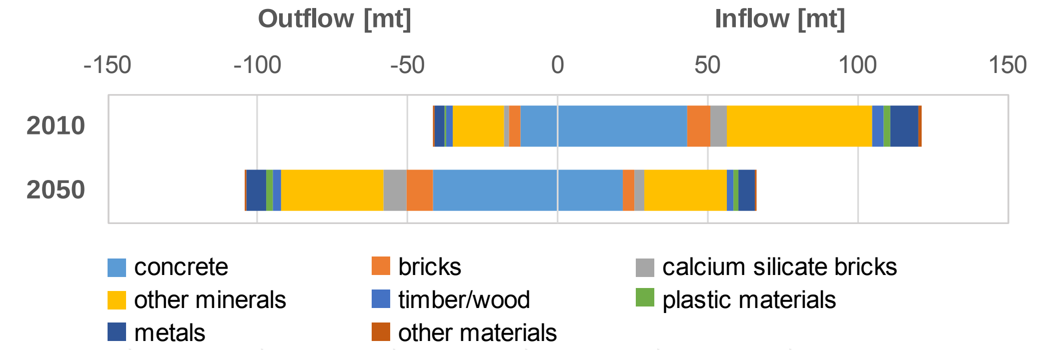
1. INTRODUCTION

Megatrends such as climate change, demographic change and sustainability require an adaptation of the European building stock to new needs. So far, public debate on environmental issues has often focused on improving energy efficiency and reducing greenhouse gas emissions. However, a key protection goal for sustainable development is also the conservation of resources - in this case of raw materials. From this perspective, the building stock represents a material storage that has to be well-managed. This raises the question of which material flows are triggered by the conversion of the building stock towards sustainability and resilience, how regional material cycles can be closed in the interest of conserving resources, and how the construction materials industry could use the possibilities of a circular economy. This paper is providing theses in order to address fields of action for retrofitting processes in the European building stock, taking Germany as a case example. These are based on knowledge and experience from past work (see references) and point the way for future research activities.

2. FACTS AND FIGURES ON MATERIAL FLOWS IN THE BUILDING STOCK

Outflow will exceed inflow

Studies on existing buildings and their dynamics in Germany emphasize the importance of the existing building stock and its significance as a resource of the future. Currently the German material stock in buildings is 186.6 t/cap., and it still continues to grow. The ratio between inflow and outflow in 2010 was 3:1. However, this development is not continuing. According to (Gruhler and Deilmann, 2016) the ratios will upturn completely to 1:1,6 in 2050. In addition, the material compositions of the flows will shift (fig 1).



Data source: Gruhler and Deilmann 2016

FIGURE 1. MATERIAL FLOWS OF THE GERMAN BUILDING STOCK IN 2010 AND 2050.

Retrofitting or Deconstructing & Recycling?
This will shift the attention increasingly towards existing buildings. The question is how buildings can be used resource-efficiently in the longer term and which material costs for adjusting buildings can be justified from an efficiency point of view. Experience is available for the case of energetic renovation. If the buildings are in good structural condition, up to 80% of the materials can be saved compared to a similar new building by continuing to use building components like load bearing structure. For buildings in poor condition, this is significantly reduced and is also not economically feasible (Deilmann and Gruhler, 2009).

Are the potentials being used?
Recycling (RC) potentials have so far largely remained unexploited. In Germany, less than 2% of aggregates in concrete are currently replaced by RC aggregates. Significantly more is possible. Approx. 50% of the outflow of concrete and bricks can be processed to RC aggregates, taking into account processing losses. In the production of concrete, up to 45% of the aggregates can be replaced by RC aggregates. Prerequisite is a high continuous quality management from demolition to admixture (Schiller, Gruhler and Ortlepp, 2017).

Shortages of material sources and sinks
For certain materials, shortages are to be expected in the future. Gypsum, for example, has so far been largely extracted from residuals from exhaust gas purification in power plants. With the phasing out of fossil energy, this source will run dry. However, gypsum is very well suited for recycling if it is specifically removed from the outflow mass flow. There are additional shortages in the broader sense for other bulk building materials such as aggregates. The extraction of these materials leads to changes in landscapes and entails costly recultivation measures. So far, construction waste has also been used for backfilling. In Germany, tighter regulations regarding soil and water protection will make this increasingly difficult. Thus the pressure on landfills will increase if it is not possible to further expand recycling (Schiller, Müller and Ortlepp, 2017).

Does existing knowledge address requirements of planning?
All the aforementioned aspects in mind, it can be observed that to date, a lack of information hinders the operationalisation of the concept of a more circular economy during retrofitting processes. There are already concepts available like building passport (Miller and

Lützkendorf, 2016). and material cadastre that provide information with regard to buildings and building stocks, but most of those projects are concentrating on available data or only a certain part of the building stock instead of the actual information required by actors responsible for decisions along the material chains. An ongoing research project that started in 2018 and from which thematically relevant first results will be presented is focusing on the latter aspect.

3. CONCLUSION

Based on the above-mentioned experiences, the following recommendations can be given regarding resource conservation during retrofitting processes:

(1) Buildings that are suitable to meet both current and future user requirements and whose space is still in demand should be preserved and, if necessary, retrofitted towards energy efficiency and accessibility as well as resistance to the consequences of climate change.
(2) Buildings that are no longer suitable for meeting future user requirements should be dismantled and the obtained materials should be recycled.
(3) Information has to be provided in such a way that the respective planning processes are adequately supported. For example, knowing the material composition is beneficial for planning dismantlings. In order to secure such kind of information in the future, material inventories are suitable as a part of building passports. Furthermore, models for the regional material flows should be developed, which allow forecasting the further development of the local building stock and lead to temporally and spatially differentiated information on the expected material in- and output. The basis is formed by descriptions of the regional building stock and its material composition in the form of material cadastres.
(4) For an effective urban mining and closing recycling loops, it is essential to develop informational instruments and add to already existing ones in such a way, that the actual information needs of the actors that influence the mentioned material flows are taken into consideration and are placed in the centre of attention.
(5) Circular economy-oriented retrofitting processes contribute to conserving resources as well as sinks. Both are essential components of comprehensive resource efficiency strategies that aim not only at saving raw materials but also at an extended understanding of resources, also taking into account e.g. soil and water protection.

REFERENCES

Deilmann, C. and Gruhler, K. (2009). Residential and Commercial Buildings in Rural Areas - Refurbishment or New Construction. Czasopismo Techniczne, [online] Volume 106(5), pp. 37-46. Available at: https://suw.biblos.pk.edu.pl/resourceDetailsRPK&rId=1558&rsAt=0 [Accessed 21 June 2018].

Gruhler, K. and Deilmann, C. (2016). Resource saving potentials through increase recycling in the building sector – sensitivity studies on current and future construction activity. In: Sustainable Built Environment Conference 2016 in Hamburg: Strategies, Stakeholders, Success factors. [online] Hamburg: ZEBAU, pp. 1010-1019. Available at: https://publikationen.bibliothek.kit.edu/1000051699 [Accessed 21 June 2018].

Miller, W. and Lützkendorf, T. (2016). Capturing sustainable housing characteristics through Electronic Building Files: The Australian Experience. In: Sustainable Built Environment Conference 2016 in Hamburg: Strategies, Stakeholders, Success factors. [online] Hamburg: ZEBAU, pp. 190-199. Available at: https://publikationen.bibliothek.kit.edu/1000051699 [Accessed 21 June 2018].

Schiller, G., Gruhler, K. and Ortlepp, R. (2017). Continuous material flow analysis approach for bulk nonmetallic mineral building materials applied to the German building sector. Journal of Industrial Ecology, [online] Volume 21(3), pp. 673-688. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12595 [Accessed 21 June 2018].

Schiller, G., Müller, F. and Ortlepp, R. (2017). Mapping the anthropogenic stock in Germany: Metabolic evidence for a circular economy. Resources, Conservation and Recycling, [online] Volume 123, pp. 93-107. Available at: http://dx.doi.org/10.1016/j.resconrec.2016.08.007 [Accessed 21 June 2018].

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Harmonized Digital Information Platform for Energy-Efficient Building Renovation

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ABSTRACT

There is an urgent need to scale up and accelerate energy-efficient building renovation in Europe for achieving the EU 2030 Climate Targets. The rise of Building Information Modelling (BIM) and the current availability of a range of BIM authoring, analytical and management tools should facilitate the process. However, until now the level of BIM adoption for renovation projects is too low. The main bottlenecks are: the lack of open and affordable digital information platforms, constraints to interoperability between various BIM tools and data, and inadequacy of techniques and skills to apply BIM for existing buildings. This paper proposes viable solutions to enable all stakeholders collaborating in renovation projects to reduce the time, effort and cost of BIM preparation, adoption and future maintenance.

Keywords: Energy-efficient building renovation; Building Information Modelling; digital platform

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Rationale and literature review

The building sector accounts for 40% of the total energy consumption and 36% of CO2 emissions in the European Union (EU) (Carvalho et al., 2016). Most of the existing building stock has reached the age for renovation as 90% of the total stock was built before 1990 and 40% of this stock was built before 1960 when building energy performance standards had not yet been published. Since 2010 the renovation market has surpassed the construction of new buildings. However, even though there is an increasing trend in renovation, the rate of the renovated building stock is still very low. Moreover, projects aimed at energy-efficient deep renovation level only take 1% share. Building Performance Institute of Europe (BPIE) and the European Parliament (“Boosting Building Renovation”, 2016) indicated that only 5% of the renovation projects so far reduced energy consumption by 60–90% while renovation projects that targeted near Zero Energy consumption were negligible.

The rapid development and growing acceptance of Building Information Modelling (BIM) in the building industry can support the upscaling and acceleration of energy-efficient building renovation, and the minimization of the gap between the targeted and realized energy performance of the renovated buildings. Building Information Modelling (BIM) has many definitions, but the recurrent theme refers to a framework which standardize various processes related to information production, exchange and management (Jung and Joo, 2011) with a specific focus on the integration of information across the entire supply and use chain of buildings (Smith et al., 2017). While BIM originally was intended for adoption to support design and engineering, it rapidly caught the attention of researchers and practitioners facing challenges during other phases of the building life cycle, such as renovation. While previous researchers reported on the benefits of adopting BIM for renovation projects (Volk et al., 2014; Aldanondo et al, 2014; Joblot et al., 2017), few renovation projects have yet adopted BIM.

The adoption of BIM for renovation projects still faces challenges in terms of: availability and affordability of digital information platforms to accommodate BIM approach; limited compatibility of the BIM tools and constraints to the interoperability of the BIM data; and lack of efficient and standardized procedures for As-Built data acquisition, As-Built and As-Renovated modelling, energy simulation, configuration of renovation design solutions, and long-term maintenance of the BIM renovation data.

Objective, type and research method of this paper

This research paper aims to analyses the actual bottlenecks of BIM for renovation projects, and subsequently propose a holistic research and demonstration approach to generate viable technical, economic, social and organizational solutions for all involved stakeholders. The research relies on an empirical method as it begins by defining the five main stages of actual BIM-based renovation projects, namely: 1) data acquisition from existing buildings; 2) renovation design; 3) building performance analysis; 4) execution of renovation works; and 5) long-term monitoring and maintenance. Subsequently, transdisciplinary innovations will be developed in the areas of: renovation process, time and resource management; ICT tools and standards; and social and legal aspects of BIM.

The proposed process innovation aims to resolve the fragmentation and segmentation within the renovation value-chain and solution development. Process re-engineering will result in a seamless integration and quick installation of Plug-and-Play (PnP) building products for renovation, which will reduce the renovation time substantially. The empirical performance of PnP renovation solutions has been proven among others in the on-going EU research project titled P2Endure (www.p2endure-project.eu). A new roadmap for BIM-based renovation that incorporates the main BIM-related renovation tasks, stakeholders' roles, required competencies and collaboration agreements will be established.

The proposed ICT innovation focuses on multi-dimensional BIM development and application, to be introduced as "10D BIM toolset for renovation". It covers: renovation project initiation and programming (1D); document management (2D); building and aerial scanning, modelling and technical clash detection (3D); time scheduling (4D); cost estimation (5D); Building Energy Modelling (BEM) and sustainability analysis (6D); facility management and post-renovation maintenance (7D); long-term monitoring and processing of real-time data (8D); connection from buildings to the surrounding environments, energy grid and local regulations (9D); and continuous updates of buildings', occupants' and energy performance in BIM Renovation Passports (10D).

This innovation goes beyond the state-of-the-art concept of 7D BIM, which presents a fully mature, comprehensive model for maintenance, operation and for facility management. This encompassing digital model contains all project relevant information of the entire process (planning, execution, management, operation and use). (Redmond et al., 2012; Georgis & Kovacic, 2016). The sixth and seventh dimensions are often not distinguished due to their contextual proximity. However, the lack of agreement on labelling BIM for facility management dimension as 6D or 7D, drives researchers toward avoiding the use of a specific label. Other than that, BIM for facility management has been on researcher radar for a while (Becerik-Gerber et al., 2011). Current trends indicated the need of expanding BIM dimensionality to allowing smarter ways of collecting, processing and using the information through the building life-cycle towards creating a digital representation of the real-word asset, coined as “digital twin”.

Such a multi-dimensional application of BIM for renovation should take certain social and legal aspects into account, most importantly the privacy, ethics and security of BIM data compliant to the European Union's new General Data Protection Regulation (GDPR) that comes into force on 25 May 2018. Therefore, social and legal innovations related to BIM for renovation will build upon the theory by Hoepman (2018) on “the 7 principles of Privacy-by-Design” and implement “the 8 Design Strategies for software design based on Privacy-by-Design”.

Empirical research will also be conducted in testing, validation and demonstration of the proposed innovations in real building renovation projects. This paper describes the selection of the case studies, definition of the use cases of BIM for renovation, and plan for pilot implementation of the research outcomes. The main goals of this empirical research activity are to implement the innovative BIM solutions in real renovation projects; to measure the real impacts with regards to energy-efficiency performance and user comfort; and to establish the evidence of the level of adoption and best practices of BIM for renovation.

Empirical results and practical / managerial implications

The expected main results from research as described in this paper is a “harmonized digital information highway” for energy-efficient building renovation, which consists of: a cloud-based BIM platform that is open, affordable and user-friendly; a set of inter-operable BIM tools –existing and new ones– connected through the BIM cloud platform; and validated and standardized procedures for BIM-based activities throughout the whole renovation process. The information content for this digital information highway will be derived from the BIM data of the case studies and will include preliminary BIM Renovation Passports.

This paper presents the preliminary empirical results of BIM for renovation from real case studies in Spain, Italy and Poland. The real case in Spain is performed in conjunction with a large-scale EU innovation project under Smart Cities program. Several residential building blocks in Vitoria-Gasteiz, Basque Country, Spain are being retrofitted to achieve than 60% energy savings at deep renovation level according EU Energy–Efficiency Directive (EED) and European Commission document SWD(2013 143 final). This paper discusses the follow-up steps to accelerate the BIM adoption process at district renovation scale using the new digital information platform and associated tools. The other case studies (in Italy and Poland) are conducted within the EU research project P2Endure. In these cases, As-Built BIM has been created based on 3D laser and thermal scans, the Plug-and-Play renovation products have been configured using a BIM parametric modeler, and a preliminary energy calculation has been performed. Particularly for the Italian case, two different methods, each with a specific software for BEM, have been applied. This paper discusses the findings and lessons-learned from each method, and recommends optimization solutions to reduce the required time for BIM-to-BEM.

This paper finally presents the plan for wide-scale replication of the pilot experience and industrial exploitation of the newly developed and validated BIM solutions. There main pathways for such an upscaling action have been paved. The first one will accommodate immediate replications among the existing building stock owned by the clients and stakeholders involved in the real case studies. The second one will promote replications in future renovation projects which will be selected through a pan-European “BIM for Renovation Competition”, which will be organized by involving clients aiming to set up plans for BIM-based renovation, design and construction firms aiming to carry out the renovation projects, and BIM consultants and software vendors aiming to provide their services and products to the clients and stakeholders in renovation projects. Finally, the third one will encourage embedding the knowhow in professional trainings and practices of architects, HVAC engineers, energy specialists, and construction firms through the European and national professional associations.

References

Aldanondo, M., Barco-Santa, A., Vareilles, E., Falcon, M., Gaborit, P. and Zhang, L., 2014, July. Towards a BIM approach for a high performance renovation of apartment buildings. In IFIP International Conference on Product Lifecycle Management (pp. 21-30). Springer, Berlin, Heidelberg.

Becerik-Gerber, B., Jazizadeh, F., Li, N. and Calis, G., 2011. Application areas and data requirements for BIM-enabled facilities management. Journal of construction engineering and management, 138(3), pp.431-442.

Carvalho, J.P., Silva, S.M. and Mateus, R., 2016. Using BIM to streamline the energy renovation processes of residential buildings during the early design stages. In International Conference on Sustainable Housing Planning, Management and Usability (Sustainable Housing 2016) (pp. 435-444). Green Lines Institute for Sustainable Development.

Gourlis, G. and Kovacic, I., 2016. Building Information Modelling for analysis of energy efficient industrial buildings – A case study, 68, pp. 953-963

Hoepman, J-H., 2018. Privacy Design Strategies (The Little Blue Book). Creative Commons Attribution - Non Commercial 4.0 International License (CC BY-NC 4.0).

Joblot, L., Paviot, T., Deneux, D. and Lamouri, S., 2017. Literature review of Building Information Modeling (BIM) intended for the purpose of renovation projects. IFAC-PapersOnLine, 50(1), pp.10518-10525.

Redmond, A, Hore, A., Alshawi, M. and West, R., 2012. Exploring how information exchanges can be enhanced through Cloud BIM, 24, pp. 175-183

Smits, W., van Buiten, M. and Hartmann, T., 2017. Yield-to-BIM: impacts of BIM maturity on project performance. Building Research & Information, 45(3), pp.336-346.

Volk, R., Stengel, J. and Schultmann, F., 2014. Building Information Modeling (BIM) for existing buildings—Literature review and future needs. Automation in construction, 38, pp.109-127.

Jung, Y. and Joo, M., 2011. Building information modelling (BIM) framework for practical implementation. Automation in construction, 20(2), pp.126-133.

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Circular Building Potential within the Energy Transition for Residential Buildings in the Netherlands: a Case Study of the Utrecht-Lunetten District.

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ABSTRACT

Recently the Dutch national government decided that natural gas extraction from the Groningen field will in time be fully ceased. For the built environment as one of the main consumers of natural gas multiple transition scenarios are in this context conceivable, depending on technological choices but mainly depending on policy goals. In carrying out the Dutch energy transition a focus should be set on CO_2 reduction (in compliance with Paris agreements), but at the same time one could focus on circular material use as well (in line with the Dutch national target to have a fully circular economy by 2050). But what are the environmental impacts if we also take into account material related CO_2 emissions and other environmental impacts based on LCA data? And what is the best strategy? In this paper a model is developed providing insight into the material flows and associated environmental impacts for various transition scenarios. The Utrecht neighborhood of Lunetten will serve as case study. The options for circular material use within the transition is explored and their environmental impacts are being assessed. For example we show that if a circular scenario for façade reconstruction is followed we can save approximately 3 tons of embodied CO_2 per dwelling.

Keywords: Energy Transition, Circular Renovation, Embodied Carbon

1. The necessity of a transition to a Natural Gas Free Built Environment

To natural gas extraction related earthquakes in Groningen, climate change and the possible future dependency on foreign natural gas recently led in the Netherlands to the formulation of policy goals to phase out natural gas extraction in Groningen by 2030 (Rijksoverheid, 2030) and minimize its use in the Netherlands. For the built environment as one of the main consumers of natural gas in the Netherlands various alternatives for the heat supply are considered that will also result in considerable energy savings (and thereby also CO_2 emission reductions). This research will look in these energy saving & CO2 reduction alternatives but some additional steps are taken on top of this. This research will also take a closer look to the environmental impacts based on LCA data for various transition scenarios. The additional environmental impacts this study focusses on are embodied energy & carbon. Besides this the CPG methodology which is a methodology to measure circularity in buildings (Mak, 2017) will be used to measure and analyze the circular potential of various transition scenarios. For this research it has been chosen to use a specific neighborhood as an example: the Utrecht neighborhood of Lunetten.

2. A description of the CIMFA-Model

For this project a model is currently developed which is able to analyze the environmental impacts and the degree of circularity for various natural gas transition scenarios over a certain period of time for the Lunetten neighborhood. This model deploys a newly developed geometric model (the CIMFA-Model or Circular Material Flow Analysis Model) that uses a limited amount of reference houses (archetypes) to determine all material stocks in the current building stock inside a neighborhood in the present situation, as well as all inflows and outflows for various renovation scenarios. Besides this the environmental and energy impacts of these scenarios will be analyzed with the help of "GPR Gebouw" which is a software tool to determine the degree of sustainability of an individual building (GPR, no date). This combination of tools makes it possible to determine the circular potential of the different transition scenarios.

The CIMFA-model for the analysis of material flows in relation to the transition scenarios is specifically for this research newly constructed. In the basis the model is kept as simple as possible (little information needed / needed information is easily accessible and can be easily inserted into the model. This will minimize the amount of needed specialist knowledge. The model offers the possibility to calculate the material flows of various retrofit scenarios in a neighborhood based on the measurements of a limited amount of reference houses. In this each reference house represents a certain category of dwellings in the neighborhood. Note in this that the reference houses used in this model are specially modelled for this neighborhood (based on blueprints of individual houses in Lunetten) to give an as accurately possible view on the housing stock in the neighborhood. The amount of categories in the model is made optional allowing to even insert each house separately.

2.1. Model Design

The housing stock of Lunetten are classified according to construction year, house type and dwelling space. From this several reference houses will be created that correspond with the archetypes (RVO-voorbeeldwoningen) that were made by order of the Dutch national government. To keep the analysis clear the archetypes divided into two categories namely row house and apartment. These two categories represent together 96% of the housing stock of Lunetten. These two main categories are then further subdivided into categories that further distinguish houses based on dwelling space. An example for instance is that one reference house of 65m² can represent all houses that fall within an dwelling area of 60m² - 69m² (so the calculation is only performed for the 65m² example house and the results are multiplied with the amount of houses within the category of 60m² - 69m²).

2.2. Scenarios

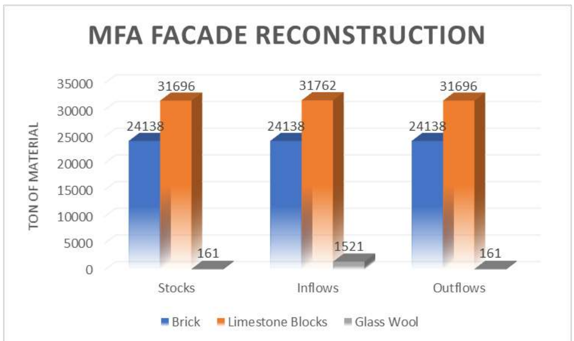
In the next step various scenarios are created. The main goal of each of the scenarios is: transitioning from a housing stock with a heat supply depending on natural gas towards a housing stock with a natural gas free heat supply. For this target various scenario variants are made for energy (in GPR-Gebouw) and material flows (in the CIMFA-Model). From an energy point of view there has been chosen for transition scenarios that form the two extremes in order to give a bandwidth between all possible transition scenarios. One scenario will focus on heavy insulating measures combined with heat pumps. The second scenario uses high temperature district heating as heat supply source which is a scenario that encompasses minimal changes to the existing housing stock. Finally as a form of reference next to the retrofit scenarios there is a demolishment and newly built scenario created (heat supply by heat pumps). These scenarios on its turns also influence material flows. Within each energy transition scenario we further subdivide variants based on material impacts (optimizing either on CO_2 reductions of materials used or on circular material use). For this last one we mainly consider the re-use of outflow materials on site / within the neighborhood, secondary material use and the use of biobased materials. For each of the scenario variants the environmental impacts are assessed in the entire range based on LCA data. For this the national standardized LCA methodology for buildings (MPG-method) is used as well as the IPG method (Alsema et al, 2016).

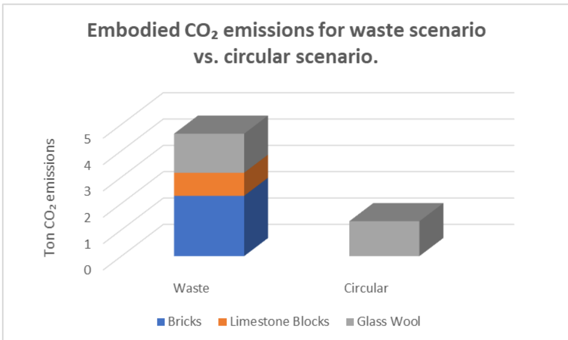
2.3. Interpretation of the results

Based on the options mentioned above results will be obtained from both the GPR software tool as well as the specially made CIMFA-Model. These results will be combined in an additional Excel tab in which then based on indicators such as operational energy, operational carbon, embodied energy, embodied carbon and CPG statements will be made about the environmental impacts of the various scenarios (specifically viewed upon per indicators but also broader taking multiple indicators in account at the same time). From this analysis should come forward what the best transition scenario is for Lunetten when more than just the environmental impact of energy are taken in account.

3. Results of the Model

For this ongoing research some preliminary results have been made for the scenario of demolishment and new construction of the façades. In the figure on the left side we consider the total material flows in the neighborhood for this demolishment and new construction of this operation. We have investigated how a waste scenario (all outflows will be landfilled) compares with a circular scenario (all outflows will be reused as much as possible) with regard to embodied CO_2 emissions. Results in the figures below show that the circular scenario leads to considerably less material inflows and embodied CO_2 emissions than the waste scenario. If a circular scenario for façade reconstruction is followed we can save approximately 3 tons of embodied CO_2 per dwelling. To put this figure in perspective: a standard 70s row house overall comprises approximately 55 tons of embodied CO_2, while the operation energy consumption of such a house is in the present situation around 5-6 tons of CO_2 per year. An circular scenario for façade renovation can thus save around 50% of the yearly energy-related CO_2 emissions. What we show as a preliminary result as work in progress, more realistic and comprehensive renovation scenarios (including various energy supply transformations) will be considered in the next few months.





REFERENCES

Alsema E.A., Anink, D., Meijer, A., Straub, A., & Donze, G. (2016). 'Integration of Energy and Material Performance of Buildings': I=E+M, *Energy Procedia,* 96, 517-528.

GPR (no date) GPR Gebouw maakt duurzaam bouwen meetbaar en bespreekbaar [Online]. Available at: https://www.gprsoftware.nl/gpr-gebouw/ (Accessed: 21 June 2018)

Mak, J. (2017) Circulair is meetbaar [Online]. Available at: https://www.duurzaamgebouwd.nl/circulaire-economie/20170411-circulair-is-meetbaar (Accessed: 21 June 2018)

Rijksoverheid (2018) Kabinet: einde aan gaswinning in Groningen [Online]. Available at: https://www.rijksoverheid.nl/actueel/nieuws/2018/03/29/kabinet-einde-aan-gaswinning-in-groningen (Accessed: 21 June 2018)

The Ministry of Infrastructure and the Environment & The Ministry of Economic affairs(2016) A Circular Economy in the Netherlands by 2050 [Online]. Available at: https://www.circulaireeconomienederland.nl/rijksbreed+programma+circulaire+economie/Programma+documenten/handlerdownloadfiles.ashx?idnv=806449
(Accessed: 23 March 2018)

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Solutions for the coming retrofit challenge: Towards modular, mass customised and circular retrofit products

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ABSTRACT

Creating a circular economy within the built environment is one of today's big societal challenges. The housing stock can be made more circular through circular retrofitting. However, approaches and solutions integrating circularity within housing retrofit are lacking. This paper focusses on developing circular housing retrofit approaches and solutions for Dutch housing constructed between 1970 and 1990.

Through analysis of the Dutch context it is found that 'all-in-one' retrofits are difficult to realise. An alternative circular retrofit approach is developed by combining identified circular retrofit principles. This approach applies modular (allowing component-by-component retrofit), 'mass customisable', and circular retrofit products, employing natural maintenance moments to gradually create a circular housing stock. This approach is tested through the development of a concrete retrofit product: The Circular Kitchen, and is found to have the potential to support circular housing retrofit in practice.

Keywords: Circular economy; Housing retrofit; Retrofit products

1. INTRODUCTION

The building sector consumes 40% of natural resources globally, produces 40% of global waste and 33% of emissions (Ness and Xing, 2017). Creating a circular economy in the built environment is therefore of vital importance to become a sustainable sector. The housing stock, as an important part of the built environment, can be used more circular through retrofitting. Yet, retrofitting can also be carried out so that the stock is made circular at all levels: the housing stock, dwelling, components, parts and materials. However, approaches and solutions integrating circularity within housing retrofit are lacking. Therefore, in this paper the aim is to develop circular housing retrofit approaches and solutions, focussing on Dutch housing constructed between 1970 and 1990. A logical initial context, as it contains 24% of the Dutch housing stock and will be in need of retrofitting in the coming decades.

This paper consists of three parts. First, the retrofit challenge in the Dutch context is analysed. Through literature study, circular retrofit principles are identified and translated into a circular retrofit approach for the Dutch context. Finally, to illustrate and empirically test this approach, a concrete retrofit solution is developed and tested together with industry.

2. RESULTS

2.1. Exploring the retrofit challenge in the Dutch 70's and 80's housing stock

The housing stock constructed between 1970 and 1990 forms 24% of the Dutch stock (Het ministerie van BZK, 2016, CBS, 2011) and will be in need of retrofitting in the coming decades (Ubink and van der Steeg, 2001). The stock is characterised by (mostly) low-rise dwellings, diversified designs and fragmented mixed-ownership. Most housing is in a 'decent' state of maintenance with – on average – an energy label D or C. There is need for adaptations and improvements but the stock is not (yet) in disrepair. The diversity, fragmentation and state of the housing makes the commonly applied 'all-in-one' sustainable retrofits difficult to realise (Meulendijks, 2010). Hence, other approaches are needed to realise sustainable – and circular – retrofits. Although such an approach would be tailored to the Dutch context, it could be beneficial to housing with similar characteristics throughout Europe.

2.2. Developing a circular retrofit approach: towards modular, mass customised and circular retrofit products

In this paragraph, possible retrofit and circular retrofit principles are identified through literature study and translated into a circular retrofit approach. Meulendijks (2010), Ubink and van der Steeg (2001) and Brinksma (2017) suggest retrofitting solutions for the Dutch 70's and 80's housing stock should be (1) able to spread the retrofit investment over multiple retrofit cycli and (2) should accommodate different retrofit needs and practices from professional and private owners through customisation. Finally, (3) the retrofit solutions should be adaptable: accommodate future changes. By integrating these principles with circular retrofit principles - identified from circular construction precedents such as 'Open Building' (Habraken, 1961) and circular product design principles as developed by the Ellen MacArthur Foundation (2017), van den Berg and Bakker (2015) and Bakker et al. (2014) - a circular retrofit approach is developed for the Dutch context. This approach proposes that the Dutch 70's and 80's housing is retrofitted by applying retrofit products which are:

1. Modular. Buildings consist of many components such as installations, kitchens and facades. Allowing component-by-component retrofit, as opposed to 'all-in-one' retrofit, can provide an answer to the fragmented mixed-ownership and relatively 'minor improvements' needed in the stock. Furthermore, by applying modular circular retrofit products, natural maintenance moments can be employed to gradually create a circular housing stock.
2. Suitable for 'mass customization'. Mass customisation combines the advantages of mass- and industrial production with the advantages of product customisation. Mass customisation can accommodate the different retrofit needs of professional and private owners, increase affordability and synergises with circular design principles such as: improving product quality, retrofit product and (sub)component standardisation, and offering (update) choices to users.
3. Designed to integrally make the housing stock at each level, gradually, circular through:
   i. A design developed according to the 9 circular 'R's': Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover, for which circular retrofit product design principles have been specified.
   ii. A supporting supply chain model in which the 9 circular R's are arranged.
   iii. A supporting business model with a value proposition stimulating the 9 circular R's.

2.3. Developing and testing an exemplary modular, 'mass customisable' and circular retrofit product: The Circular Kitchen

To illustrate and empirically test the proposed approach, an exemplary modular, 'mass customisable', and circular retrofit product – the Circular Kitchen (CIK) – is described in the following paragraph. The CIK was developed to a proof-of-principle in co-creation with the TU Delft, AMS-institute, housing associations (as initial target group) and industry partners. The CIK was developed 'integrally' including the technical (design), supply chain and business model. The CIK consists of a dockingstation in which kitchen modules can be plugged in and out. The modules consist of a frame to which 'function modules' (appliances) and 'style packages' (front, countertop) can be easily attached using click-on connections.

The professional side of the business model applies a purchase with take-back model including circular KPI's and service subscriptions. A dealer offers extra kitchen modules and style packages to tenants through a variety of financial arrangements that motivate returning the product after use, like lease and sale-with-deposit. After use, the kitchen producer and dealer 're-loop' the dockingstation, kitchen modules, parts and materials in a 'Return factory' and local 'Return streets'. The CIK was validated with a preliminary LCA, and was tested for economic viability with housing associations, industry, and users.

3. CONCLUSION

The goal in this paper was to develop circular housing retrofit approaches and solutions, focusing on Dutch housing constructed between 1970 and 1990. It was found that in this context 'all-in-one' sustainable retrofits are difficult to realise due to the fragmented ownership, the state of the housing stock and diversified dwelling designs. An alternative circular retrofit approach was developed which applies modular (allowing component-by-component retrofit), 'mass customisable', and circular retrofit products, allowing natural maintenance moments to be employed to gradually create a circular housing stock. As an example and test, the Circular Kitchen (CIK) was described. The approach presented in this paper has the potential to support circular housing retrofit in practice, both in the Dutch context and for housing elsewhere with similar characteristics. However, development and testing of (more) circular retrofit products is necessary to create a fully circular housing stock over time.

FURTHER READING

1. The CIK: the Circular Kitchen. In CIK, the circular kitchen is developed to a prototype, and large demonstrator with Delft University of Technology, Chalmers University of Technology, AMS-institute, housing associations and industry. Further reading: https://www.tudelft.nl/en/architecture-and-the-built-environment/research/research-themes/circular-built-environment/projects/cik-the-circular-kitchen/
2. REHAB: In the REHAB project, modular, mass customisable and circular retrofit products are developed with Delft University of Technology, housing associations and industry and tested within housing retrofit projects.

REFERENCES

BAKKER, C. A., DEN HOLLANDER, M., VAN HINTE, E. & ZIJLSTRA, Y. 2014. *Products that last,* Delft, TU Delft.

BRINKSMA, H. 2017. *Toekomstbestendig renoveren.* PhD dissertation, TU Delft.

CBS. 2011. *Statistisch jaarboek* [Online]. http://www.cbs.nl/statistischjaar-boek2011: CBS. [Accessed 17-06-2018].

ELLEN MACARTHUR FOUNDATION. 2017. *The Circular Design Guide* [Online]. https://www.circulardesignguide.com/. [Accessed 17-06-2018 2018].

HABRAKEN, N. J. 1961. *De dragers en de mensen: het einde van de massawoningbouw,* Amsterdam, Scheltema & Holkema.

HET MINISTERIE VAN BZK 2016. Cijfers over Wonen en Bouwen 2016. Den Haag: BZK.

MEULENDIJKS, T. 2010. *De weg terug vinden in de bloemkoolwijk: zoektocht naar een nieuwe stedelijke vernieuwingsroute.* Masterthesis, Radboud Universiteit Nijmegen.

NESS, D. A. & XING, K. 2017. Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model. *Journal of Industrial Ecology,* 21**,** 572-592.

UBINK, M. & VAN DER STEEG, T. 2001. *Bloemkoolwijken: Analyse en Perspectief,* Amsterdam, SUN.

VAN DEN BERG, M. R. & BAKKER, C. A. A product design framework for a circular economy. Product Lifetimes and The Environment (PLATE), 2015 Nottingham, UK. Nottingham Trent University.

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Cost Efficient Way to Retrofit Residential Buildings

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ABSTRACT

This paper presents the interesting renovation technologies used, the results achieved, and the observations made in the EU-GUGLE project. The EU-GUGLE project demonstrated the improvements in the energy efficiency of residential blocks of flats. Four of the demonstration projects were located in Aachen, one in Bratislava, two in Milan, five in Sestao, eight in Tampere and 18 in Vienna. The energy savings objectives were ambitious, ranging from 40 to 80% depending on the site. The methods used for achieving the desired energy savings included reduction of thermal losses, improvements in energy performance and increased own renewable energy production.

Even though the sites were in different climatic zones, the renovation concepts employed greatly resembled one another. A typical renovation concept included improvement of the insulation of the building envelope, new windows and on-site energy production or efficient use of energy with the help of heat pumps. If not prevented by protection regulations, the buildings were also fitted with a solar power plant. The project started in April 2013 and will end in March 2019. Monitoring data is already available on a large share of the demonstration sites from one or more

Keywords: Residential building; Deep renovation

1. Background

As regards the goals and implementation of the Energy Performance of Buildings Directive, the focus is shifting to the renovation of existing buildings. The first articles referring to existing buildings presented in the recasting of the directive in 2010 (EU, 2010). The EU Member States were also tasked with examining the life cycle costs of the requirements, or to steer their choices in such a manner that the savings achieved in the energy costs during the life cycle of buildings would be taken into account in order to counterbalance the investments costs.

Meeting this requirement demanded that Member States examine their renovation concepts and develop modelling and simulations tools suited for the purpose. One article of the Energy Efficiency Directive required that every Member State draw up a deep renovation strategy of their own building stock (EU, 2012). In connection with the latest amendment, the deep renovation strategy will become article 2a of the Energy Efficiency Directive (EU, 2018). These EU-level requirements are a major driver for promoting the renovation of existing buildings.

The guidelines, used in the improvement of the energy efficiency of buildings both in directives and at a practical level is the Kyoto Pyramid: 1) improve energy efficiency; 2) ensure efficient energy use; 3) increase the use of renewable sources of energy; 4) monitor and control consumption and 5) choose the energy source.

2. EU-GUGLE CASES

The concepts for improving the energy efficiency of buildings were examined in real, inhabited residential blocks of flats (Morshita et al. 2016). The sites were either mutually owned by the residents or rental flats. All owners had both financial and operational requirements for their renovation projects. The renovation concepts were to include new and efficient, but reliable and reasonably priced technology for ordinary people − not for those first to adopt new technologies. These starting points were also the condition for the replication of the renovation concepts.

In every city, the planning of the demonstration projects was supported by a research organisation. The role of the organisation depended on the cultural factors in each country and on whether the demonstration site owner − the party that commissioned the renovation − was a professional owner of rental apartments or a residential community consisting of lay people. Particularly, the owners of rental apartments were interested in testing new technologies and extending the refurbishment to cover various buildings in the same area. Lay communities, on the other hand, needed support in the acquisitions and the implementation of the project. In addition to technical improvements, efforts were made to increase the awareness of the residents of the importance of saving energy with different campaigns and even personal consultations.

The condition of the demonstration sites and their energy performance was examined thoroughly before planning the renovation measures, using thermography, for example. The expected energy savings in terms of energy needs, energy use and non-renewable primary energy and reductions in greenhouse gas emissions were simulated centrally, using the dynamic simulation software.

The impact of the measures on the energy consumption of the buildings was measured in all demonstration sites. In a few sites, the impact of renovation on the indoor air conditions was also measured. The post-renovation assessment also included evaluation of the profitability of the demonstrations.

3. IMPROVING MEASURES AND ENERGY SAVINGS

In Aachen, the primary energy savings were amounting to 66-85% and achieved by means of structural improvements, construction of a regional district heating network and by using heat pumps to recover heat from collecting sewers for heating the buildings. People were encouraged to reduce the use of household electricity by providing personal guidance and by distributing “energy saving boxes” to the residents, with such items as an energy consumption meter and compact fluorescent light bulbs.

In Bratislava, purchased primary energy savings of 90% were achieved by improving the structures of the building envelope and by installing novel apartment-specific ventilation equipment, heat pumps, heat storages and solar panels. The demonstration site was detached from the district heating system. The new heating system has smart control to avoid expensive grid electricity.

In Milan, the purchased energy savings were 66-82 % by means of structural improvements, heat pumps and solar panels. In Milan an special attention was paid to the human comfort issues.

In Sestao, 80-90 % primary savings were achieved with the help of structural improvements in the building envelope and the implementation of biomass central heating systems. The district heating system produces heat from biomass. Smart meters control DHW and heating consumption. Data platform besides collects the energy consumption also guides residents to save in their energy bills.

In Tampere, achieved primary energy savings were amounting 35-70 %. Structural improvements of the building envelope and more efficient use of energy as well as own renewable energy production were used. Six of the eight sites remained in the district heating system, but the use of exhaust air heat pumps reduced need of district heating significantly. Two of the sites replaced district heating with a ground-source heat pump.

In Vienna, the primary energy savings of 60-80 % were achieved using various concepts, such as structural improvements on the buildings, centralised heat production and installation of solar panels.

4. CONCLUSION

Even though the demonstration projects received reasonable EU grants and many of the sites were granted national assistance, it was still difficult to find demonstration sites. Even changes in local politics delayed the launch of some projects. The relationship between the input and output in projects aimed at improved energy efficiency is considered low, or expensive in relation to the benefits achieved. For this reason, the demonstration of new cost-efficient renovation concepts has attracted a lot of positive attention and increased refurbishment activity in cities.

Among the technologies used in the demonstration projects, the heat pumps turned out to be the most effective way of reducing energy consumption. The sources of heat for the heat pumps, both the house-specific and regional ones, included outdoor air, exhaust air and heat from sewage as well as ground heat. Own solar energy production increases the profitability of a heat pump.

Heat pumps, as well as other technical systems, increase electricity consumption. Technologies that reduce the use of electricity include such systems as lighting control with presence detectors. Own solar panels reduce the need to consume bought electricity. Another objective of the EU-GUGLE project was to support the reduction of the use of household electricity by means of electricity meters and the feedback given by them (smart meters; demand response). In a limited amount of trials, these measures also produced good results.

REFERENCES

EU (2010) Directive 2010/31/EU - The energy performance of buildings (Available online http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&rid=1 [accessed 28/11/2016])

EU (2012) Directive 2012/27/EU - The energy efficiency (Available online http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&rid=1 [accessed 28/11/2016])

Morishita, N., Heidenreich, M., Hemmers, R., Vankann, M., Sahakari, T., Vainio, T., Treberspurg, M., Öterreicher, D. (2016) EU-GUGLE: A sustainable Renovation for Smarter Cities from a Pilot Project, Smart and Sustainable Planning for Cities and Regions p. 353-382.

EU (2018) Commission welcomes Council adoption of new Energy Performance in Buildings Directive (Available online https://ec.europa.eu/info/news/commission-welcomes-council-adoption-new-energy-performance-buildings-directive-2018-may-14_en [accessed 17/6/2018])

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Development of a Financial Feasibility Tool for Circular Components: The Case of the Circular Kitchen

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ABSTRACT

Creating a Circular Economy within the built environment is an important societal challenge. A viable way towards a more circular built environment is to gradually replace building components with circular products.

In circular product development, business models, industrial models and design strategies need to be implemented in conjunction. Even though the financial incentive is key for companies, the financial feasibility of circular products is rarely estimated beforehand. Therefore, in this paper a tool is developed that compares the financial feasibility of circular product designs and industrial models to each other and to the business-as-usual scenario.

The tool calculates the Total Cost of Ownership of a component and is tested through the case of the Circular Kitchen. It is concluded that further work can be done to improve the user-friendliness of the tool.

Keywords: Circular Economy; Financial feasibility; Building products

1. INTRODUCTION

1.1 Circular Building Components

The building sector is responsible for up to 40% of all waste, 40% of all material consumption and 33% of all emissions (Ness and Xing, 2017). Creating a Circular Economy (CE) within the built environment could be a way to end this wasteful practice. The housing stock is a substantial part of the built environment. A viable way towards a more circular housing stock is to gradually replace building components with circular products.

1.2. Financial Feasibility Tool

When developing circular products, business models, supply models and design strategies need to be implemented in conjunction (Bocken *et al.*, 2016). Therefore an a priori vision or goal of circularity needs to be implemented. For companies, financial incentives play a significant role in the determination of their vision and goals. In literature the competitive advantage for companies embracing a CE perspective is often stated (Ellen

MacArthur Foundation, 2014; Lacy and Rutqvist, 2015). However, the (financial) advantage of circular product ownership and production over that of non-circular products is rarely quantified during the product's development. Therefore, in this paper a tool that compares the financial feasibility of circular product designs and industrial models to each other and to the business-as-usual scenario is developed. Through literature study, manners by which the financial feasibility can be compared are identified. The tool is then developed and tested through the case of a circular building component in consultation with industry partners.

2. RESULTS

2.1. Total Cost of Ownership

One of the major barriers to overcome in circular component implementation is the possible high cost of investment. Total Cost of Ownership (TCO) is a method that looks beyond initial purchase to include many other costs throughout the period of ownership (Ellram, 2011). TCO therefore offers a long-term perspective that is appropriate for CE strategies.

2.2. TCO Model

The tool is based on replaceable and repairable parts that can have different lifespans to incorporate the CE strategy of designing for disassembly and modularity (Van den Berg and Bakker, 2015). The TCO of the component is therefore calculated through the sum of the net present value of the component's parts. The net present value of the parts is determined by the sum of the expected cost throughout one period.

The parameters used in the tool have been determined in consultation with industry partners and include lifespan, purchase, installation, transport, removal, residual value, repair, lifetime prognostics, energy and water consumption, process management and return on investment of the (new) production line.

The tool can be used in different types of ownership (building owner as owner, manufacturer as owner and user as owner). The type of ownership determines whether parameters such as return on investment of the production line are relevant for the scenario.

To incorporate systems thinking, which is an integral part of developing circular products, the parameter of residual value is included. The residual value determines the value of parts after removal from the component. This can be a positive value, in the case of a circular component, or even negative in the case of waste from a non-circular component.

2.3. Testing the tool through the case of the Circular Kitchen

The case of the Circular Kitchen (CIK) is used to test the tool. The CIK is being developed in co-creation with housing associations and industry partners. For the CIK project, four scenarios based on three different strategies and the business-as-usual scenario were compared. Scenario 1 is based on an investment cost-driven strategy. Scenario 2 and 3 are based on a value-driven strategy and scenario 4 is based on the strategy of low operational costs. Data for scenario 0 (business-as-usual), as well as the discount rate for all scenarios, were gathered from the housing associations. Estimations of parameter values for the other scenarios were done in cooperation with industry partners. All scenarios are based on the housing association as owner. Table 1 shows the averages and totals of the input per category per scenario and shows the corresponding TCO.

TABLE 1. AVERAGES AND TOTALS OF THE INPUT AND THE OUTPUT OF THE SCENARIOS USED.

	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
All scenarios are based on a discount rate of 3% and a period of 80 years	**Business-as-usual**	**Cost Driven**	**Value Driven A**	**Value Driven B**	**Operational Cost Driven**
1. cost of the component	€ 1.970,00	€ 640,15	€ 1.181,50	€ 1.181,50	€ 1.181,50
2. average cost per part	€ 1.970,00	€ 106,69	€ 168,79	€ 196,92	€ 337,57
3. average lifespan of parts in years	20,00	21,67	47,29	55,00	37,14
4. component installation costs	incl. in 1.	€ 400,00	€ 640,00	€ 320,00	€ 320,00
5. component removal costs	incl. in 1.	€ 560,00	€ 480,00	€ 320,00	€ 320,00
6. component residual value	incl. in 1.	€ 128,03	€ 945,20	€ 827,05	€ 118,15
7. component transport cost	incl. in 1.	€ 50,29	€ 25,21	€ 33,09	€ 0,00
8. number of repairs during lifespan	80	11,00	2,10	3,10	0,00
9. average repair costs	€ 26,61	€ 40,00	€ 40,00	€ 50,00	€ 68,57
10. repair management costs per year	€ 0,39	€ 0,39	€ 0,39	€ 0,39	€ 0,39
11. average lifetime prognostics costs	€ 0,00	€ 4,18	€ 4,30	€ 4,18	€ 7,43
12. lifetime prognostics management costs per year	€ 0,00	€ 0,39	€ 0,39	€ 0,39	€ 0,00
13. reuse, refurbish, recycling system management costs per year	€ 0,00	€ 12,16	€ 12,16	€ 12,16	€ 12,16
Component TCO	**€ 3.929,38**	**€ 5.398,22**	**€ 4.496,20**	**€ 3.295,39**	**€ 3.648,33**

3. CONCLUSION & DISCUSSION

This paper aimed to develop a tool that compares the financial feasibility of possible circular product designs and industrial models to each other and to the business-as-usual scenario. It was found that through TCO it is possible to look beyond initial purchase. The CIK project is used to test the tool. The results show that this method can support owners to make choices in the development and implementation of circular building components.

The tool is developed for and tested through building components but can be equally useful for estimating other (circular) product feasibility with minor adjustments. The data used in the test is largely based on estimations and more accurate data is needed. Further research can contribute the user-friendliness of the tool. Furthermore, the reference study period used in the model was based on the initial expected lifespan of the circular component as a whole. In future calculations, studying the outcomes of scenarios with varying reference periods can be useful.

FURTHER READING

CIK: The Circular Kitchen. https://www.xxxx.nl/en/architecture-and-the-built-environment/research/research-themes/circular-built-environment/projects/cik-the-circular-kitchen/

REFERENCES

Bocken, N. M. P. *et al.* (2016) 'Product design and business model strategies for a circular economy', *Journal of Industrial and Production Engineering*, 33(5), pp. 308–320. doi: 10.1080/21681015.2016.1172124.
Ellen MacArthur Foundation (2014) 'Towards the Circular Economy Vol.3: Accelerating the scale-up across global supply chains', *Ellen MacArthur Foundation*, (January), pp. 1–64. doi: 10.1162/108819806775545321.
Ellram, L. M. (2011) 'A Framework for Total Cost of Ownership', *International Journal of Logistics Management*, 4(2), pp. 49–60. doi: http://dx.doi.org/10.1108/09574099310804984.
Lacy, P. and Rutqvist, J. (2015) 'Gaining the Circular Advantage', in *Waste to Wealth*. London: Palgrave Macmillan UK, pp. 24–32. doi: 10.1057/9781137530707_3.
Ness, D. A. and Xing, K. (2017) 'Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model', *Journal of Industrial Ecology*. Wiley/Blackwell (10.1111), 21(3), pp. 572–592. doi: 10.1111/jiec.12586.

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A Review of Research Investigating Indoor Environmental Quality in Sports Facilities

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ABSTRACT

Abstract –Very few research studies appear to have investigated indoor environmental quality in sport facilities, in particular aspects related to thermal comfort, lighting comfort, acoustic comfort, and indoor air quality. This study provides a review of such studies. The review shows that most studies assessed indoor air quality and thermal comfort but not acoustic comfort and lighting comfort in those buildings, emphasizing the need for more studies focusing on these aspects of indoor environmental quality in sport facilities.

Keywords: Indoor environmental quality, sport facilities

1. INTRODUCTION

People spend approximately 90% of their time indoors (Evans and McCoy, 1998) and are thus exposed to a number of indoor environmental quality (IEQ) conditions that may affect them. In the literature, these conditions are divided into the following main aspects: 1) thermal comfort, 2) lighting comfort, 3) acoustic comfort, and 4) indoor air quality (IAQ), all of which together determine IEQ (Wong, Mui and Hui, 2008; Frontczak and Wargocki, 2011; Frontczak, Andersen and Wargocki, 2012; Sakhare and Ralegaonkar, 2014). A review of the literature showed that while a number of studies investigated these aspects in office buildings, school buildings and to a lower extent in residential buildings, very few studies (e.g. (Alves et al., 2013; Cianfanelli et al., 2016) investigated them in sports facilities. This study provides a review of the IEQ literature on sport facilities in order to identify potential knowledge gaps and make recommendations for the way forward. It is the first review of its kind in the literature.

2. METHOD

The literature review involved searching the academic databases of Scopus, Science Direct, Compendex Web and Google Scholar for relevant journal papers. The search focused on studies investigating IEQ in gymnasiums and fitness centres, which assessed at least one aspect of IEQ, regardless of the year of publication. It excluded studies focusing on the IEQ of ice arenas and swimming pools. The search used the keywords: {“Indoor Environmental

Quality” OR “Thermal Comfort” OR “Acoustic” OR “Lighting” OR ‘Visual” OR ”Noise” “OR “ Indoor Air Quality”} AND {“ Sports” OR “Gym” OR “Athletic halls” OR “Fitness”}.

3. RESULTS AND DISCUSSION

A total of 21 papers met the search criteria outlined above. Of them, 16 (e.g. Revel and Arnesano, 2014a; Cianfanelli et al., 2016; Slezakova et al., 2018) were published after 2010 and one (Lee, Chan and Chiu, 1999) before 2000, reflecting recent increasing interest in the topic. With respect to location, 19 of the 21 studies (e.g. Alves et al., 2013; Revel and Arnesano, 2014b; Slezakova et al., 2018) investigated IEQ in sport facilities in Europe, with the other two focusing on sport facilities in Hong Kong (Lee, Chan and Chiu, 1999) and Brazil (Lia et al., 2015). None of the studies reviewed were conducted or focused on buildings in North America.

Of the 21 studies, 15 (e.g. Braniš and Šafránek, 2011; Slezakova et al., 2018) evaluated IAQ in which particulate matter was the most frequently studied indoor air pollutant. Eight (e.g. Revel and Arnesano, 2014b) Ramos, Wolterbeek and Almeida, 2014) assessed thermal comfort, with air temperature and relative humidity being the most frequent investigated thermal comfort parameters. Three studies (Jedovnický and Peter, 2014; Jurak et al., 2015; Lia et al., 2015) assessed acoustics, while no study appears to have investigated lighting comfort in sport facilities. All 21 studies used physical measurement or sampling to assess IEQ, with three of the 21 studies (Revel and Arnesano, 2014a; 2014b; Cianfanelli et al., 2016) surveying users of those facilities in addition to physical measurements to evaluate their IEQ satisfaction. The number of investigated facilities ranged from one gymnasium (Castro et al., 2015) to 11 fitness centers (Ramos, Wolterbeek and Almeida, 2014), and measurements were conducted over one day (Ramos et al., 2016) to 177 days (Braniš and Šafránek, 2011).

The studies’ results emphasized the effect of occupancy on sport facilities’ IEQ. For example, Ramos et al. (2016) found higher bacterial concentration at night (i.e. at peak occupancy) compared to mornings (i.e. when occupancy is lower). Some researchers such as Žitnik et al., (2016) and Slezakova et al., (2018) found a positive correlation between particulate matter concentration and the number of occupants. Others (e.g. Ramos, Wolterbeek and Almeida, 2014; and Slezakova et al. 2018) found that a number of IEQ parameters in those facilities exceeded recommended levels, reinforcing the need to improve IEQ in those facilities to bring these parameters within recommended thresholds.

Cianfanelli et al. (2016) found discrepancies between objective (e.g. physical measurements) and subjective (e.g. surveys) measures of comfort, while Revel and Arnesano, (2014b) found them to generally agree with one another. This shows the importance of not relying on one type of measurements alone to interpret IEQ results as both complement one another. EPA (2003) recommended conducting in addition to these two types of measurements a building inspection and interviews with building owners or managers to better investigate a building’s systems and conditions.

4. CONCLUSION

Given the focus in existing studies on evaluating IAQ and thermal comfort in sport facilities, there’s a need for more studies that investigate other aspects in those buildings such as acoustics and lighting comfort separately and in relation to one another. Moreover, there is a remarkable gap in assessing these buildings’ IEQ in North America in comparison to Europe, thus the need to encourage such studies in Canada and the United States.

FURTHER READING

This paper is a part of an ongoing research study aiming to evaluate IEQ in sports facilities at the University of Manitoba, Canada, using both objective and subjective measures of IAQ, thermal comfort, lighting comfort, and acoustics comfort.

REFERENCES

Alves, C. A. *et al.* (2013) 'Indoor air quality in two university sports facilities', *Aerosol and Air Quality Research*, 13(6), pp. 1723–1730.

Braniš, M. and Šafránek, J. (2011) 'Characterization of coarse particulate matter in school gyms', *Environmental Research*, 111(4), pp. 485–491.

Castro, A. *et al.* (2015) 'Indoor aerosol size distributions in a gymnasium', *Science of the Total Environment*. Elsevier B.V., 524–525, pp. 178–186.

Cianfanelli, C. *et al.* (2016) 'Environmental Quality in Sports Facilities: Perception and Indoor Air Quality', *Journal of Physical Education and Sports Management*, 3(2), pp. 57–77.

EPA, U. S. (2003) 'A standardized EPA protocol for characterizing indoor air quality in large office buildings', *Indoor Environment Division US EPA, Washington, DC*.

Evans, G. W. and McCoy, J. M. (1998) 'When Buildings Don'T Work: the Role of Architecture in Human Health', *Journal of Environmental Psychology*, 18(1), pp. 85–94.

Frontczak, M., Andersen, R. V. and Wargocki, P. (2012) 'Questionnaire survey on factors influencing comfort with indoor environmental quality in Danish housing', *Building and Environment*. Elsevier, 50, pp. 56–64.

Frontczak, M. and Wargocki, P. (2011) 'Literature survey on how different factors influence human comfort in indoor environments', *Building and environment*. Elsevier, 46(4), pp. 922–937.

Jedovnický, M. and Peter, T. (2014) 'The assessment of sports halls – The analysis of Reverberation time , Strength and Clarity', 899, pp. 517–521.

Jurak, G. *et al.* (2015) 'Acoustics in School Sport Halls and Its Implications for Physical Education', *Croatian Journal of Education*, 17(Spec. edition 3), pp. 65–95.

Lee, S. C., Chan, L. Y. and Chiu, M. Y. (1999) 'Indoor and outdoor air quality investigation at 14 public places in Hong Kong', *Environment International*, 25(4), pp. 443–450.

Lia, K. *et al.* (2015) 'Sound pressure levels measured in fitness gyms in Brazil', *Canadian Acoustics*, 43(4), pp. 19–24.

Ramos, C. A. *et al.* (2016) 'Characterizing the fungal and bacterial microflora and concentrations in fitness centres', *Indoor and Built Environment*, 25(6), pp. 872–882.

Ramos, C. A., Wolterbeek, H. T. and Almeida, S. M. (2014) 'Exposure to indoor air pollutants during physical activity in fitness centers', *Building and Environment*. Elsevier Ltd, 82, pp. 349–360.

Revel, G. M. and Arnesano, M. (2014a) 'Measuring overall thermal comfort to balance energy use in sports facilities', *Measurement: Journal of the International Measurement Confederation*. Elsevier Ltd, 55, pp. 382–393.

Revel, G. M. and Arnesano, M. (2014b) 'Perception of the thermal environment in sports facilities through subjective approach', *Building and Environment*. Elsevier, 77, pp. 12–19.

Sakhare, V. V. and Ralegaonkar, R. V. (2014) 'Indoor environmental quality: Review of parameters and assessment models', *Architectural Science Review*, 57(2), pp. 147–154.

Slezakova, K. *et al.* (2018) 'Indoor particulate pollution in fitness centres with emphasis on ultrafine particles', *Environmental Pollution*, 233, pp. 180–193.

Wong, L. T., Mui, K. W. and Hui, P. S. (2008) 'A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices', *Building and Environment*. Elsevier, 43(1), pp. 1–6.

Žitnik, M. *et al.* (2016) 'Exercise-induced effects on a gym atmosphere', *Indoor Air*, 26, pp. 468–477.