Digital tender

A report on standardization & industrialization of renovation of housing clusters in Netherlands

January 2021

Standardization & industrialization of renovation of housing clusters in the Netherlands

DIGITAL TENDER

MMIP Line: 3.2

MMIP block: Industrialization & Digitization

BTIC Mainline & wp: WP4.2: Digitization of renovation process

Activity 1

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1. Summary

The national climate agreement targets to achieve a zero-carbon emission-built environment by 2050. The renovation of 7.5 million houses must be undertaken in large scale projects to attain energy efficiency in houses which will no longer depend on natural gas. Presently, most of the renovation projects operated in the Netherlands are fragmented and custom, making sustainable home renovation a very expensive option according to the end user. The limited demand for large-scale renovation works also limits the companies to invest in industrialised production lines. The production of more standardised products for the renovation market also remains a big challenge for many service providers. On the other hand, there are also consortia that include the government, housing corporations and the companies that are developed to support the renovation of Dutch housing stock in an extensive manner. Innovative solutions that will be a breakthrough to the traditional renovation practices are required to upscale the renovation industry from a few hundred houses to 300.000 home renovations per year.

This report consists of the PDEng research work undertaken in association with work package 4.2 (Activity 1) of the BTIC project 'Integrated Energy Transition Existing Buildings' (IEBB). BTIC recommends that for the rapid upscaling of the renovation market, the demand must be brought to the market in a structured, homogeneous, bundled and (multi-year) predictable manner, so that providers can develop standardization, repeatability and industrialization of processes, as a basis for integral cost reduction and innovation. For the bundling of demand, **a housing classification system** will be designed to cluster the houses based on the characteristics which will benefit the companies to advance in standardization and industrialization. Each cluster will be consisting of houses with a volume that upgrades the renovation process as per the climate agreement and also where **mass production** of standardized products through automation, robotics & 3D-printing becomes a renovation market model. **Tendering mechanisms** and **digital tendering platforms** are also to be developed for the elaboration of goals explained in the Climate Agreement. This project aims to contribute to the development of digital tendering platforms by focusing on the development of a prototype housing clustering system, and a product specification system as part of a digital tendering platform.

For this report, the research methodologies followed are systematic literature review and online survey to analyse the **housing clustering methods, tendering mechanisms**, **successful large-scale tendering projects** followed worldwide and in the Netherlands. Research is also done for analysing the **required information for the companies to advance in standardization & industrialization**. The above mentioned and highlighted main topics are discussed in detail under the chapters 4, 5 & 6 in this report. Since this report does not follow a typical report format, an overview of the main chapters discussed are given in section 3.2.3 of this report. The results from the systematic literature review, online survey & their comparisons are discussed under each main chapter. The overall conclusions obtained from this research work is consolidated under chapter 7. Future works and the contribution to the BTIC work package are also consolidated under chapter 8.

2. Introduction

2.1 Climate Agreement

2.1.1 Background

As per the climate agreement policy [1], the main goal in the Netherlands is to achieve a 49% reduction in national greenhouse gas emissions by 2030 compared to 1990 levels. An accelerated decarbonizing pathway for the built environment envisions an increase in energy renovation rates to 2.5 % - 3 % per year, at deep renovation levels, towards 2030. Only then it is possible to achieve a fully decarbonised built environment by 2050 [2]. At this point, the deep renovation works carried out in the Netherlands is less than 0.1%[3][4]. The policy also has a vision for 2050 which is the sustainable transformation of the built environment and the insulation of 7 million homes using renewable heating [5].

The accomplishment of this goal would benefit the end user with low energy bills and comfortable living homes. This transformation can only succeed if everyone including residents, tenants, building owners, housing associations, builders, fitting businesses, etc. are able to participate and must therefore be affordable for everyone [1][5][6]. Achieving neutral housing costs is the principal objective, which can be achieved if costs can be lowered through supply-demand pooling, digitization and innovation and by securing of better financing instruments to ensure that the vast majority of residents do not pay fees for the renovation loan that exceed the gains on their energy bills. In cases where this cannot be achieved, the government may provide targeted support (subsidy).

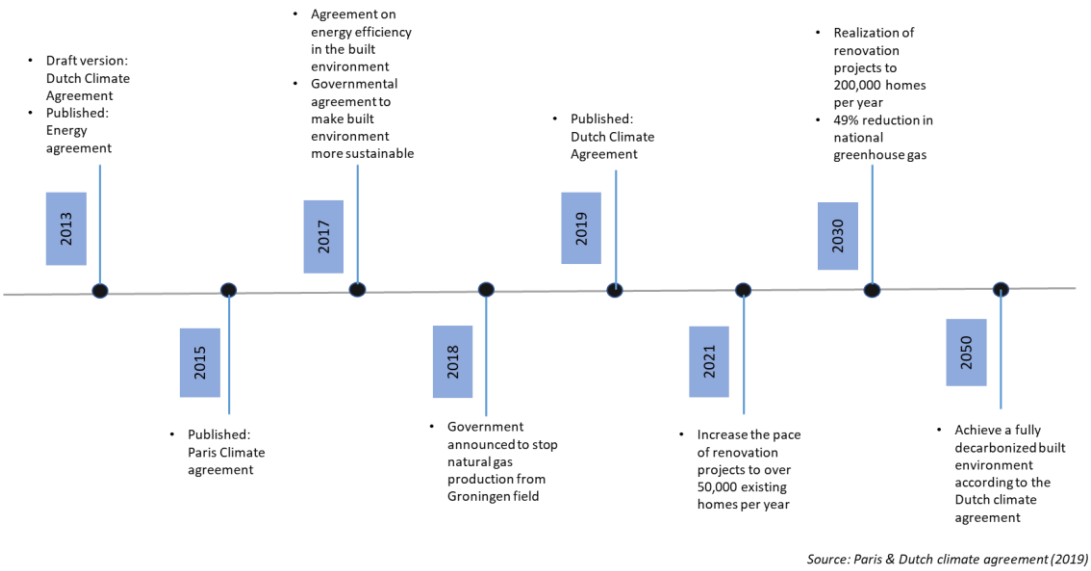


Figure 1: Climate agreement timelines regarding renovation and carbon neutral built environment

2.1.2 Target: 2030

In order to achieve the 2030 climate targets, we will have to rapidly increase the pace of renovation projects to over 50,000 existing homes per year in 2021. By 2030, we will need to have settled into a rhythm of 200,000 homes per year. The objective is to ensure a reduction of 3.4 metric tons of carbon dioxide in the built environment by 2030, compared to the reference scenario [1][5].

2.2 Dutch housing stock and renovation programs

The existing housing stock in the Netherlands needs to undergo substantial reduction in heat demand through renovation so that the built environment can be $C0_2$ neutral by 2050. The number of energy renovations are far too low, making costs to remain too high and also investments in innovations are not made. This situation requires a breakthrough and the rate of renovation of houses per year must be increased exponentially.

"Dutch climate agreement has set goals so that a large-scale renovation market consisting of 300.000 houses per year should be created, which currently does not exist yet, using innovative ideas and concepts."

Social housing associations are an important group of stakeholders because they own 30%, about 2,4 million, of the Dutch housing stock (consisting of 7,2 million dwellings) [7][8]. Homeowners are very different and their preferences regarding sustainability differ. Where one person likes to do limited jobs on the home and hardly wants any advice or unburdening, the other likes to outsource the work to a contractor or energy consultant. Some people combine sustainability with a renovation and co-finance the measures in the mortgage, while other homeowners invest in insulation measures with savings. And although more and more home owners are taking measures of their own accord, many will also wait for a collective offer [9]. This is also the reason why the current renovation market remains fragmented and highly dependent on customer requirements. New innovative approaches have to be adopted to increase the possibility of producing standardized products and processes which drive the companies to invest in industrialization. Thereby, the Dutch climate agreement envisions about initiating integral cost reduction, building up market capacity, learning processes, necessary innovations, quality assurance and scaling up the house renovation rates.

Various consortia developed under the Dutch climate agreement have accomplished national support programmes for the renovation of the Dutch housing stocks like the **Renovatieversneller (Renovation Accelerator), Natural gas-free neighborhood programs** and many others [10][12]. The consortia consist of demand sector (housing associations), supply sector (renovation solution provided companies) and the government.

These programs aim at creating a self-supporting market for energy renovations by contributing to the following:

- Transforming the housing associations to a structured, homogeneous, bundled and (multi-year) predictable market.
- Help renovation solution providers to standardize their products and processes aiding repeatability by leveling up industrialization being a base for integral cost reduction & innovation.
- Adoption and scaling up of innovations (product and process) by providing open learning environments and experiment space.

"These national support programs aim to achieve cost reduction across the entire renovation chain by encouraging the first broad market introduction of standard packages in renovation projects in which housing classification, demand bundling, digital tendering, quality assurance, knowledge sharing, innovation standardization, chain cooperation and industrialization take place."

This programme will see the development of innovations, which will lead to new energy concepts for the construction and installation contracting industry, with a significantly lower cost than the concepts that are currently on the market, caused by scaling effects. This will be a necessity in order to realize 200,000 energy renovations in the built environment each year as of 2030, which will lead to natural gas being phased out in a cost-effective manner by 2050.

The **Renovatieversneller** aims at the following elements:[11]

1. **Housing classification system:** A housing classification system is a strategy to classify the already existing housing databases into housing typologies. Each typology is clearly defined and consists of houses having very close similarity to each other. On one hand, this classification is designed by analysing the architectural and energy aspects of the houses and the homogeneity in it. On the other hand, important aspects of homogeneity among the companies are also analysed, so that uniform renovation solutions can be determined for each housing class.
2. **Demand bundling:** On the basis of the classification, housing corporations can bundle similar homes into clusters of a minimum size to be determined (possibly 500 homes) that can be used by consortia of providers, of which entrepreneurs from both large and SME companies can be part of, for 4 to 5 years. This creates a predictable and even utilization of production facilities and execution capacity. This is an important condition for industrialization and cost reduction.
3. **Digital tender:** The housing clusters can then participate in tenders on a digital platform for multiple years. The evaluation process is done by independent experts giving importance to performance and innovation criteria including an integral cost assessment.
4. **Quality assurance:** Quality assurance of the tender offers are evaluated and continuously monitored, concerning the construction, its implementation and process aspects.
5. **Knowledge sharing:** Process, costs and implementation of renovations and the performance after completion are monitored and evaluated annually, in order to improve and adjust the process, to inform market parties about the development, to feed the innovation, and to provide the central government with policy-relevant information and information.
6. **Innovation:** Relevant innovation programs are utilized and geared to the needs of the accelerating market for energy renovations, and the experience gained from the Renovation Accelerator is used to further adjust the programs.
7. **Standardization & industrialization by chain cooperation:** The housing classification system will create a large renovation market which encourages the companies to invest in industrialization to facilitate mass production of building elements. Standardized products and processes are produced by collaborating supply chain operations.

Figure 2: Dissimilar housing typologies in the Netherlands

2.3 BTIC - MMIP - Integral Energy Transition Existing Construction

Within BTIC, consortia are initiated that consist of companies, government and knowledge institutions, and that jointly propose and implement innovation processes. It monitors the progress of the innovation processes and gives its partners access to the knowledge and innovation developed. This leads to innovative technologies, processes and social innovations. The objective of the BTIC program Integral energy transition for existing buildings, IEBB, is to have the (scientific and applied) research and innovation in the field of construction, design and technology required to realize the objectives of the Climate Agreement. [12]

Many fragmented and non-integrated processes occur in current construction and renovation practices. Within the IEBB project, this leads to the following solution. Through more cooperation and integration among the homeowners, suppliers and government, end users can be offered with a more integrated, cheaper and less inconvenient renovation solution. Shortening process chains by digitization can save time and costs, while at the same time increasing the profitability of the renovation sector. This insight is not new, but for the large-scale renovation tasks for the entire Dutch building stock, breakthroughs will be necessary that go hand in hand with cultural changes with new forms of cooperation and alternative contracts. There are also opportunities to scale up tenders considerably by designing an innovative method of bundling the housing stock based on similar characteristics and similar renovation strategies. This opens a possibility of bundling the tenders. Various clients will have to work together in order to arrive at bundled tenders. For example, various housing associations, possibly together with home owner corporations (Vereniging van Eigenaars – VvEs) and individual homeowners, can arrive at joint project definitions and tenders. Matching innovative business models must be further developed. [12]

The BTIC program 'Integrated energy transition for existing buildings' (IEBB) consists of four sub-lines:

1. Renovation concepts
2. Sustainable individual heating systems
3. The transition process
4. Intelligent control of energy demand

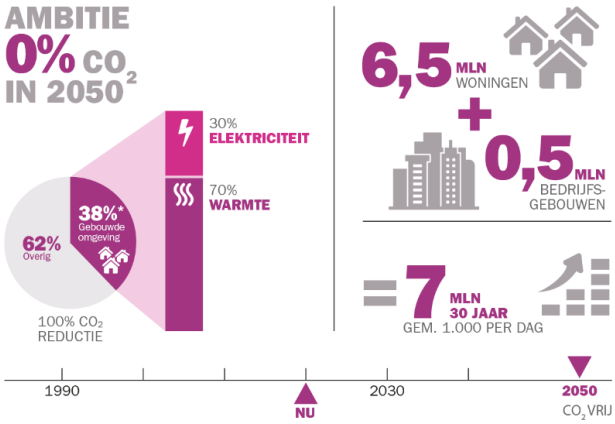


Figure 3: BTIC's ambition of housing renovation for a carbon neutral environment

Under the BTIC program 'Integrated energy transition for existing building' there are different Multi-Annual Mission-Driven Innovation Programs (MMIPs) consisting of work packages (WP). This report is submitted to the BTIC as a part of the project research work conducted under MMIP 3.2 – WP4.2 – Activity 1. More details about the work package WP4.2 –Activity 1 are detailed in the following chapter.

2.4 BTIC Mainline & work package: WP4.2 (Activity 1): Digital Tender

The PDEng (TU/e) project work with duration of 2 years is aligned with the BTIC work package 4.2 (Activity 1) starting from September 2020.

Project Target:

For the rapid upscaling of the renovation market, demand must be brought to the market in a structured, homogeneous, bundled and (multi-year) predictable manner, so that providers can develop standardization, repeatability and industrialization of processes, as a basis for integral cost reduction and innovation. For this purpose, tendering mechanisms and digital tendering platforms are being developed, among other things for the elaboration of the agreements in the Climate Agreement. This project aims to contribute to the development of digital tendering platforms by focusing on the development of a prototype housing clustering system, and a product specification system as part of a digital tendering platform.

Scope & approaches:

1. **Analysis of housing clustering methods:** Design a housing clustering system in which housing clusters are made based on certain spatial, technical and ownership characteristics, given a housing database and a renovation solution.
2. **Analysis of tendering mechanisms**: The housing clusters are tendered on a national digital platform as a multiyear process.
3. **Successful auction projects**: Based on successful projects involving large-scale procurement (e.g. offshore wind farm auctions), it is investigated how the tendering system should be set up and geared to the construction sector.
4. **The required information provision on the supply side for standardization and industrialization**: The information that is required for the companies to participate in the tender for giving accurate analysis and quotes is also important to gear their production process and achieve economies of scale. These include geometrical data of the houses, energy label data, drawings and all details required to provide a renovation solution.

Project Contribution to the objectives of BTIC- MMIPs:

1. This project ensures that large-scale tenders for home renovations can be designed according to a clustering of homes and clear specifications.
2. This project thus contributes to the development of tendering mechanisms in which demand bundling and uniform renovation packages are important elements for homes of both private owners and corporations.
3. Large scale housing renovation leads to cost reduction of innovative, standardized and industrialized products thus making this project an indispensable link to achieve product and process innovations.

PDEng Project timeline & milestones:

		Year 1 : 2020 -2021												Year 1 : 2021 -2022											
		Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4		
Task Description		sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug
1	**YEAR 1**																								
1a	Analysis of housing classification and tendering mechanism through Literature Review																								
1b	List the hierarchy of factors important for companies with respect to standardization and Industrialization																								
	Milestone: BTIC Report Submission																								
1c	Corporations, Data cleaning and prepare data ready for classification																								
1d	In-depth Interview with the selected list of companies																								
1e	Analysis of housing classification followed by Housing corporations and their tendering requirements																								
	Milestone:Framework of Housing classification system and tendering mechanism																								
2	**YEAR 2**																								
2a	Realization of tendering mechanism																								
2b	Validation of tendering mechanism through trials																								
	Milestone:Ready with Housing Classification system and tendering mechanism which can be used by Housing Corporations																								
2c	Report Writing																								

3. Research Methods

As mentioned in the previous section, this report aims at providing insights to the following:

1. Analysis of housing clustering methods,
2. Analysis of tendering mechanisms,
3. Successful auction projects &
4. The required information provision on the supply side for standardization and industrialization

All the above-mentioned mechanisms and projects were studied using the steps illustrated in Figure 4. For the purpose of data collection and analysis, systematic literature review and online survey were conducted. During the conduction of systematic literature review, Scopus and Google Scholar were used as the searching databases. The list of keywords was identified to conclude the search string. Quantitative and qualitative analysis were carried out to draw conclusions [13].

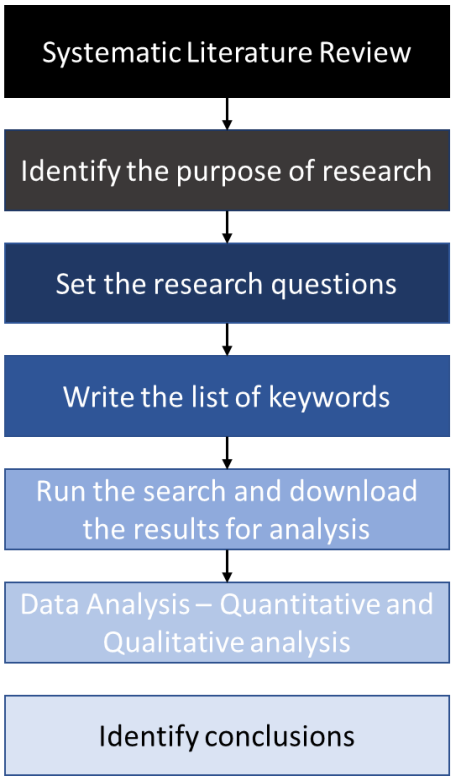


Figure 4: Systematic literature review approach

Based on the qualitative analysis of the shortlisted papers, a questionnaire was prepared, which would allow to validate literature findings in the Dutch market. An online survey was created to collect raw data of the current industrialization maturity in relevant companies in the Netherlands, and also their future vison to accomplish 2050 climatic goals along with the aim to analyze the above points. Demographic questions were also included to analyze the company profile of the respondents. This survey was designed to target responses of professionals working in various levels of a company like the top management levels (e.g. Director), project management levels and also skilled personals working in factories. The survey was prepared in Limesurvey and the links (English & Dutch) were sent to the respondents after receiving the TU/e ethical board approvals. The last step was to analyze the collected raw data according to the purpose identified in the research work. The results and the steps followed in the research methodology will be detailed in upcoming chapters.

The details analyzed through literature review and the survey conducted are illustrated in the following chapters in detail.

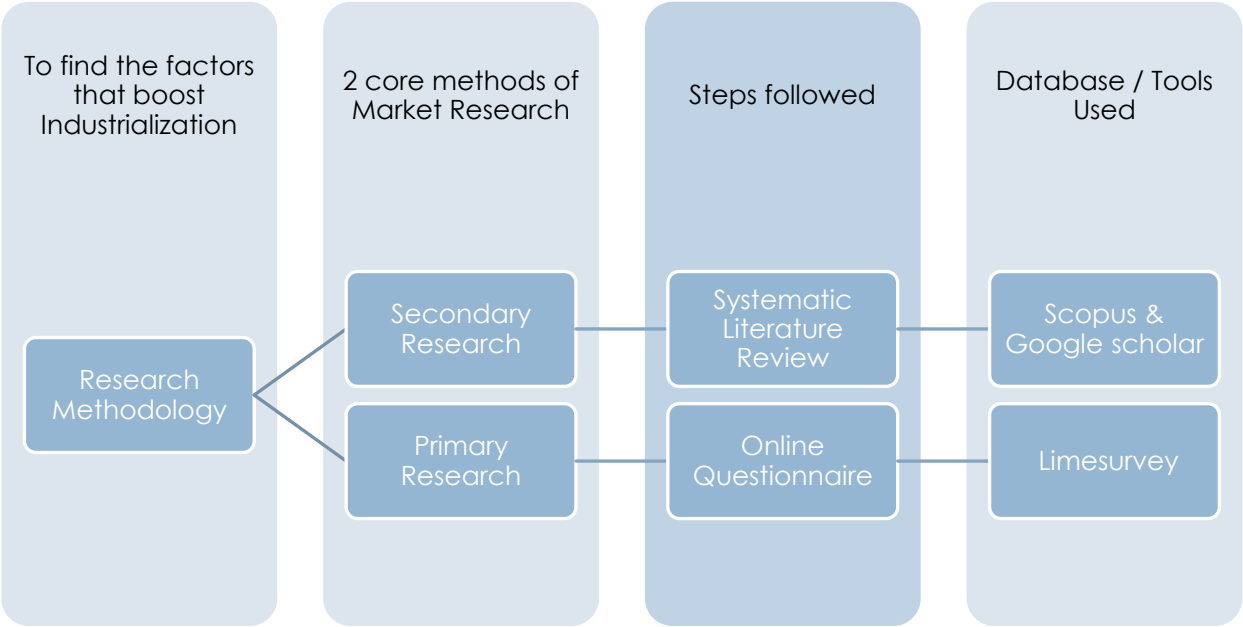


Figure 5:Details of Research methodology

3.1 Systematic literature review

As indicated in the previous chapter, the project work commenced with identifying the research problem and the learning objectives. Furthermore, research papers were shortlisted using the online libraries, Scopus & Google scholar. Certain keywords were identified for searching the scientific papers related to this project. The keywords are listed in Table 1.

Table 1 : List of Keywords used in Scopus & Google scholar

Context	Focus	Sub-focus 1	Sub-focus 2	Type
Renovation	Standardization	Tendering	Clustering	Dwelling
Retrofit	Industrialization	Procurement	Classification	Housing
Refurbishment	Industry 4.0	Auction	Archetypes	Apartment
	Construction 4.0	Bidding	Typology	Building stock
			Energy efficiency	Residential

Following is the string used in Scopus that resulted in 225 research papers.

String used : (TITLE-ABS-KEY ((renovat* OR retrof* OR refurb*)) AND TITLE-ABS-KEY (dwelling OR hous* OR apartm* OR "building stock" OR residenti*) AND TITLE-ABS-KEY (standardi* OR industriali* OR "industry 4.0"))

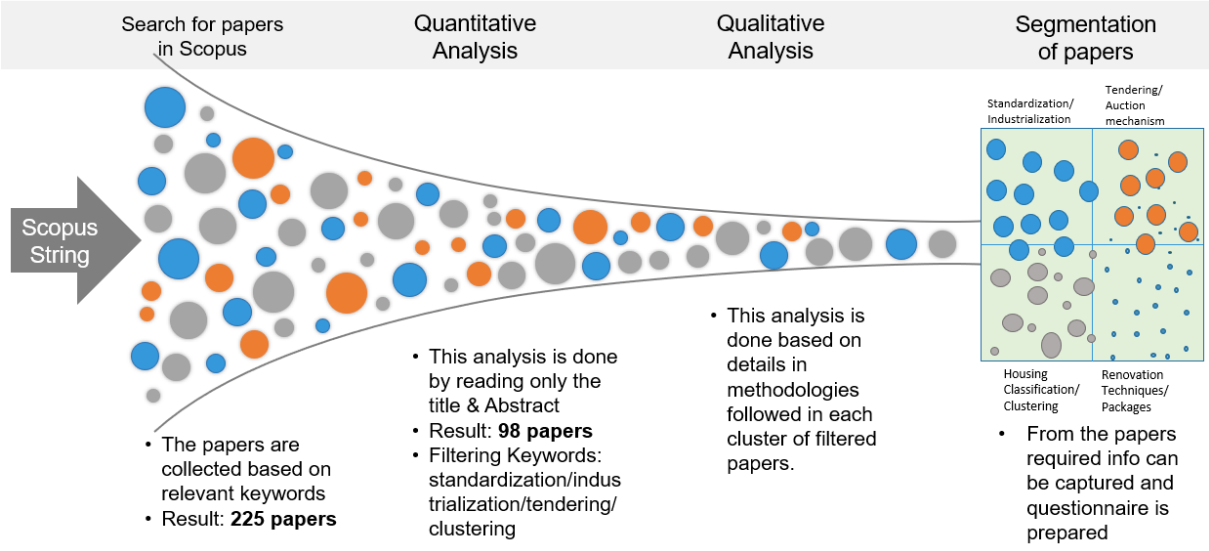


Figure 6: Systematic Literature Review

Using the above Scopus search string that resulted in 225 papers, the results were exported to a spreadsheet with all the details of the papers, such as title, author name, citation, link, keywords. Quantitative analysis was carried out by filtering the papers based on reading only the title and abstract. This step of quantitative analysis resulted in 98 papers. Qualitative analysis was conducted on these 98 papers by in-depth analysis of each paper. The focus in qualitative analysis was on the details of the papers like the methodology, results, conclusion etc. The literature survey was concluded with the segmentation of papers under various categories as illustrated in Figure 6. Through this systematic literature review, the research problems illustrated in the previous section could be studied. This step also helped in framing the questionnaire for the online survey.

3.2 Market research through online survey

A questionnaire was prepared based on the systematic literature review. It was designed in the online survey tool - Limesurvey. The questionnaire was structured to consist of 2 parts: 'demographic information' & 'Standardization and industrialization of the sustainable renovation of the existing dwelling stock'. The 'demographic information' part included 7 questions to analyze the company profile of the respondents. The second part of the questionnaire consisted of 23 questions based on the project research problems. The pdf file of the questionnaire (Dutch version) that is extracted from the Limesurvey platform is included in the appendix.

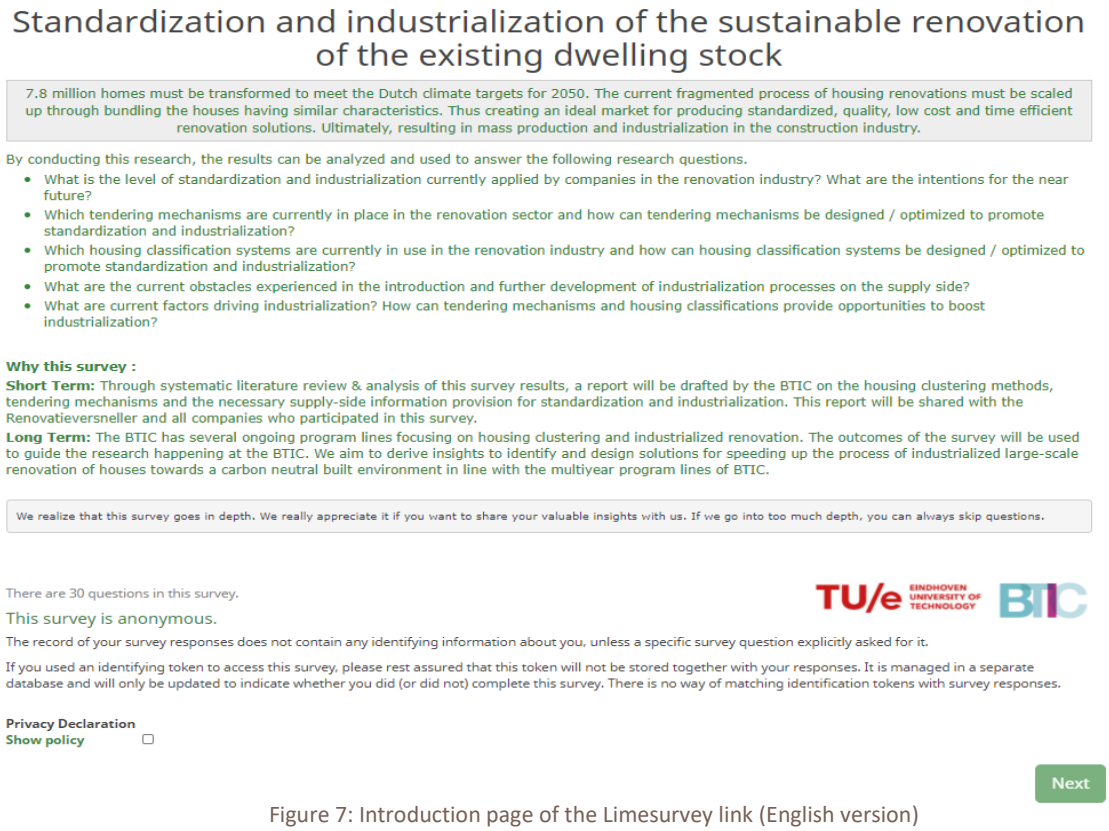
The survey targeted responses from the professionals having experience in housing renovation projects and the standardization & industrialization within their respective manufacturing processes. As a final step before the activation of the survey, the necessary TU/e ethical board approvals were acquired, and the data policy was also added to the survey. The survey was activated on the 11th of December 2020 and the last date of participation was published as 23rd December 2020 in the invitation letter. The final participation deadline was once extended till 8th January 2021.

The survey was prepared in both Dutch and English. The links were shared as a post in LinkedIn with a poster. An invitation for participation in the survey was sent to BTIC and other organizations along with

the links to circulate among the company network. The project was also introduced in the invitation mail with essential details. Following is the link to the survey and the opening page & consecutives pages of the link:

For English :
https://tueindhoven.limequery.com/973234?lang=en

For Dutch :
https://tueindhoven.limequery.com/973234?lang=nl



Standardization and industrialization of the sustainable renovation of the existing dwelling stock

7.8 million homes must be transformed to meet the Dutch climate targets for 2050. The current fragmented process of housing renovations must be scaled up through bundling the houses having similar characteristics. Thus creating an ideal market for producing standardized, quality, low cost and time efficient renovation solutions. Ultimately, resulting in mass production and industrialization in the construction industry.

By conducting this research, the results can be analyzed and used to answer the following research questions.

- What is the level of standardization and industrialization currently applied by companies in the renovation industry? What are the intentions for the near future?
- Which tendering mechanisms are currently in place in the renovation sector and how can tendering mechanisms be designed / optimized to promote standardization and industrialization?
- Which housing classification systems are currently in use in the renovation industry and how can housing classification systems be designed / optimized to promote standardization and industrialization?
- What are the current obstacles experienced in the introduction and further development of industrialization processes on the supply side?
- What are current factors driving industrialization? How can tendering mechanisms and housing classifications provide opportunities to boost industrialization?

Why this survey :
Short Term: Through systematic literature review & analysis of this survey results, a report will be drafted by the BTIC on the housing clustering methods, tendering mechanisms and the necessary supply-side information provision for standardization and industrialization. This report will be shared with the Renovatieversneller and all companies who participated in this survey.
Long Term: The BTIC has several ongoing program lines focusing on housing clustering and industrialized renovation. The outcomes of the survey will be used to guide the research happening at the BTIC. We aim to derive insights to identify and design solutions for speeding up the process of industrialized large-scale renovation of houses towards a carbon neutral built environment in line with the multiyear program lines of BTIC.

We realize that this survey goes in depth. We really appreciate it if you want to share your valuable insights with us. If we go into too much depth, you can always skip questions.

There are 30 questions in this survey.
This survey is anonymous.
The record of your survey responses does not contain any identifying information about you, unless a specific survey question explicitly asked for it.
If you used an identifying token to access this survey, please rest assured that this token will not be stored together with your responses. It is managed in a separate database and will only be updated to indicate whether you did (or did not) complete this survey. There is no way of matching identification tokens with survey responses.

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Figure 7: Introduction page of the Limesurvey link (English version)

3.2.1 Responses

The total of respondents who attempted the survey was 41. All the 41 respondents preferred to use the Dutch version of the survey. Due to the ethical board norms and approvals applied, it was not possible to receive more details of the respondents like the company name or email-id so that they could be contacted for future purposes like in-person interview.

Table 2 illustrates an overview of the responses received on the lime survey platform.

Table 2: Overview of responses received on Limesurvey

Total number of respondents who attempted the survey	41
Number of respondents answered more than 100% of the survey	14
Number of respondents answered the demographic questions (100%) and part 2 (<60%)	27

3.2.2 Demographic information from survey

For the demographic information analysis, we considered all 41 responses, namely:

- the number of respondents who answered 100% of the survey (14), and
- the number of respondents that answered 100% of the demographic questions and 60% of part 2 (27 respondents).

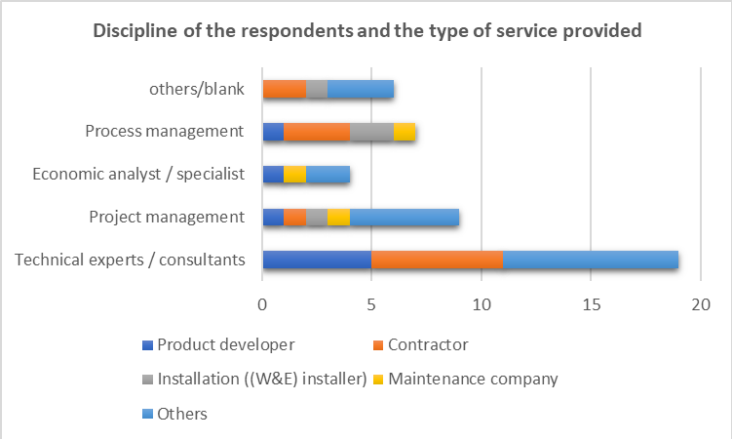


Figure 8: Discipline of the respondents and the type of service provided

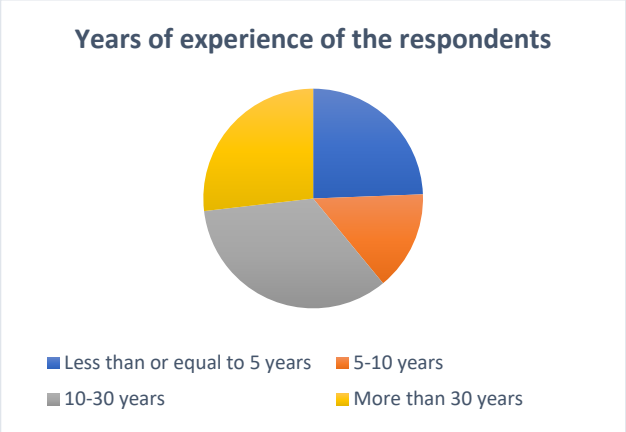


Figure 9: Years of experience of the respondents

<u>Observations</u>

- As can be seen in Fig. 8, the majority of the respondents were technical experts or consultants. Other respondents included project and process managers, as well as business analysts.
- As can be seen in Fig. 9, a large group of respondents have 10 to 30 years of experience in the construction industry. Yet, a considerable number of responses also were given by respondents with less (<10 year) and more experience (>30 year).
- The survey received responses from a mix of companies ranging from micro size (less than 10 people) to mega size (>10000 employees). From Fig. 11, it can be seen that the majority of responses comes from small to medium enterprises (SMEs), with less than 250 employees.
- Though most of them were contractors who responded, others included machine builders, professionals working in municipalities & architectural design offices and housing

corporations (considered as a company responsible for the maintenance of houses under their association). This information was obtained from the 'other' comments section of the question – Type of service provider.

- More than 70 % of the companies have their renovation projects spread across the Netherlands, as can be seen in Fig. 10. Only 25% of respondents is active only in a smaller area (province or multiple provinces).
- Figure 12 finally shows that 61% of the customers of the renovation projects are housing corporations.

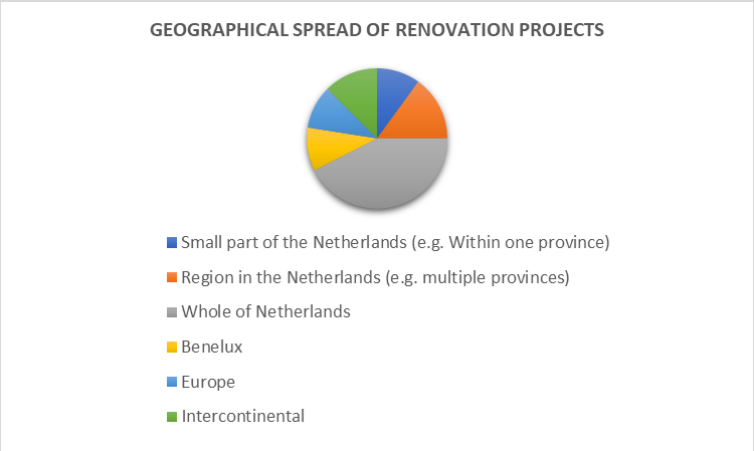


Figure 10:Geographical spread of the renovation projects of the companies

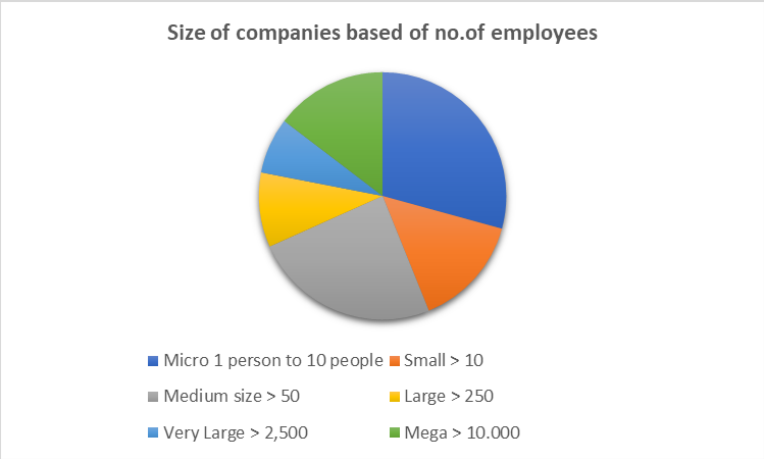


Figure 11: Size of the companies based on the number of employees

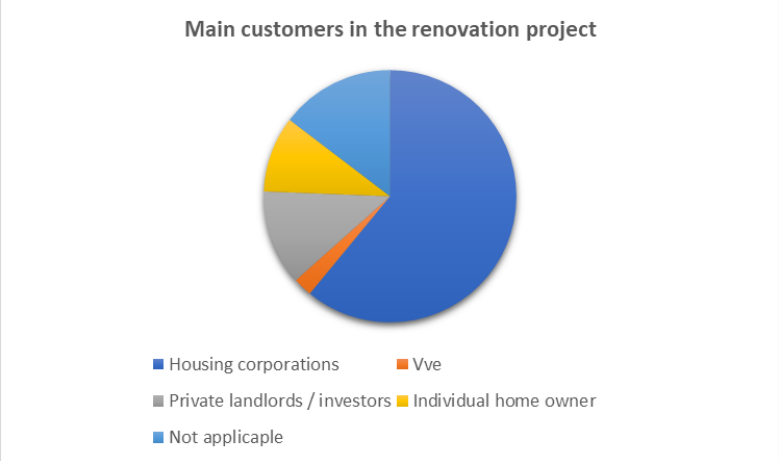


Figure 12: Main customers in renovation projects

3.2.3 Analysis of the responses to part 2 (with research questions) of the survey

The results of the analysis in part 2 of the survey are documented in the forthcoming chapters, in combination with the results from the systematic literature review.

An analysis was conducted on

- Housing clustering methods
- Tendering mechanisms
- The required information for companies to advance in standardization & industrialization

The results from are explained in detail for the above topics under the section, **x.1**. That means, section 4.1 consists of analysis of housing clustering methods through systematic literature review. The results from the online survey (Part 2) are explained in detail for the above topics under the section, **x.2**. That means, section 4.2 consists of analysis of housing clustering methods through online survey (Part 2). The list of the comparisons of results obtained from the systematic literature review and the online survey is discussed under the section **x.3.** That means, section 4.3 consists of the comparison of the results obtained from both methodologies on the housing clustering methods. This applies to the other chapters 5 & 6. Under the chapter 5, a subchapter 5.4 is also included to discuss about the information about the successful large scale projects in which tendering mechanism were successful. The design of the tendering mechanism used in such large scale projects are studied in detail in the future work of this research work to check its feasibility in large scale renovation projects.

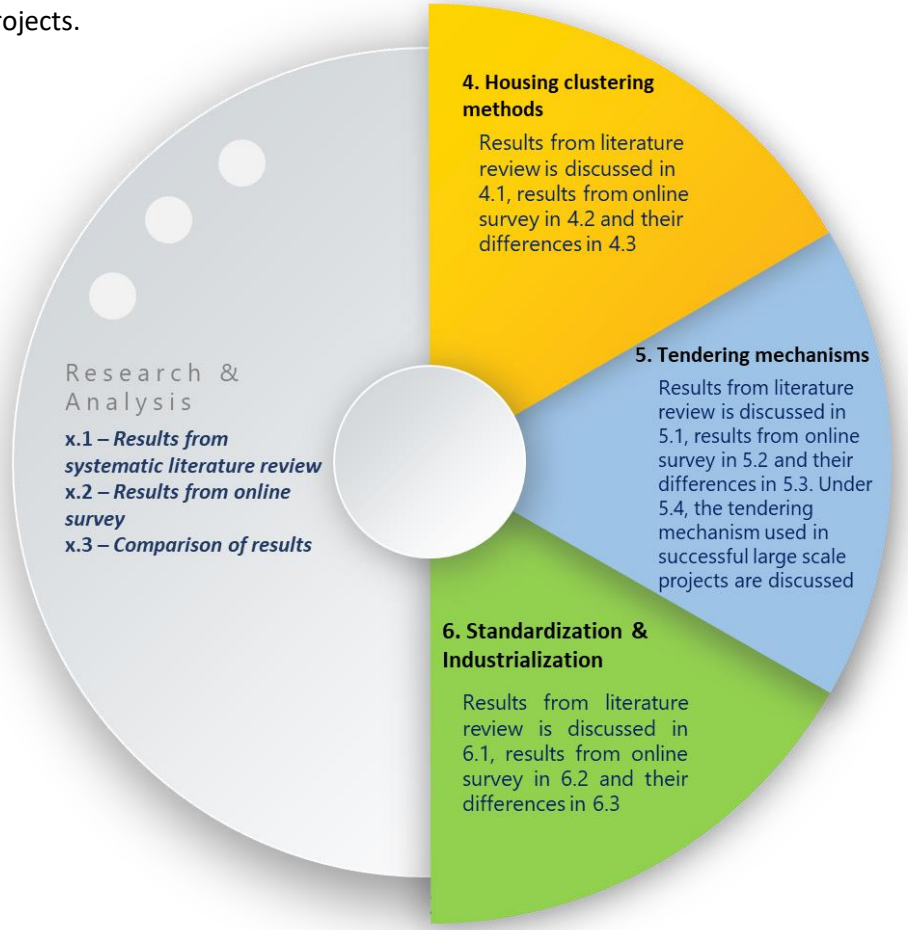


Figure 13: Pictorial representation of the structure of the upcoming chapters

4. Analysis of housing clustering methods

4.1 Analysis of housing clustering methods through literature review

4.1.1 Housing classification methods reported in scientific papers

In all the papers analyzed and also according to the climate agreements, the prevalent argument was that the built environment is responsible for a significant share of energy consumption [5][14]. Therefore it is a crucial task to conduct renovation measures on the existing building stock to achieve energy efficient & de-carbonized built environment with better performance [15]. Identification and analysis of the renovation strategy for a respective housing typology was also an important criterion. Furthermore, a great number of researchers explained that the renovation concept that they analysed is based on a sample house from a housing typology in their research papers [5] [14-17]. The typical methodology followed is to create an archetype for each significant class of household based on statistical analysis, and then examine different ways of improving energy efficiency according to the characteristics for that archetype. In most of the research papers related to house energy calculations and predictions, an archetype (also named as sample house, reference building, typical building or representative building) is defined as a house that represents the entire selected sample of houses for analysis. In the studies, it is assumed by the researchers that this sample house has very similar characteristics to the entire group and the solution applied to the sample house can also be applied to the other houses in that group. This archetype is analysed for its energy consumptions and its response to various renovation strategy alternatives are also studied. Various energy models and simulation techniques are used to analyse the impact of different energy efficiency actions on the building typology [15][17]. From the existing literature the various following characteristics were identified that are commonly considered to design a housing cluster under a housing classification system (Figure 14).[18][19]

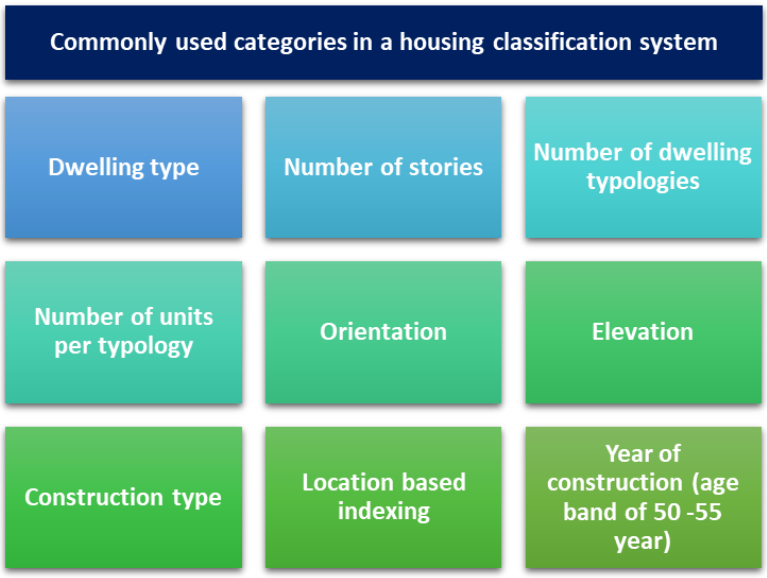


Figure 14: In a housing classification system, the housing clusters are defined using one or more of the above characteristics.

The geometric & thermal characteristics used to define a sample house of a selected housing cluster are shown in figure 15 & 16 respectively [5] [14-17].

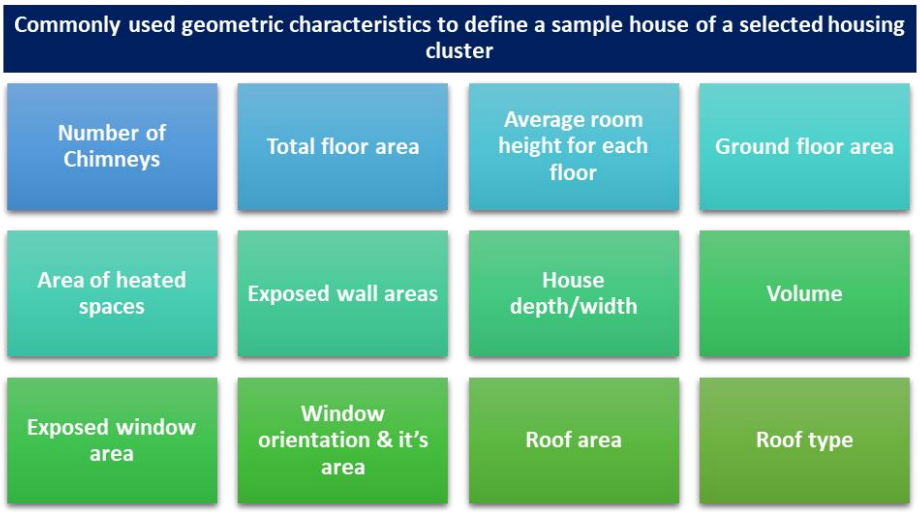


Figure 15: Geometric characteristics of a sample house

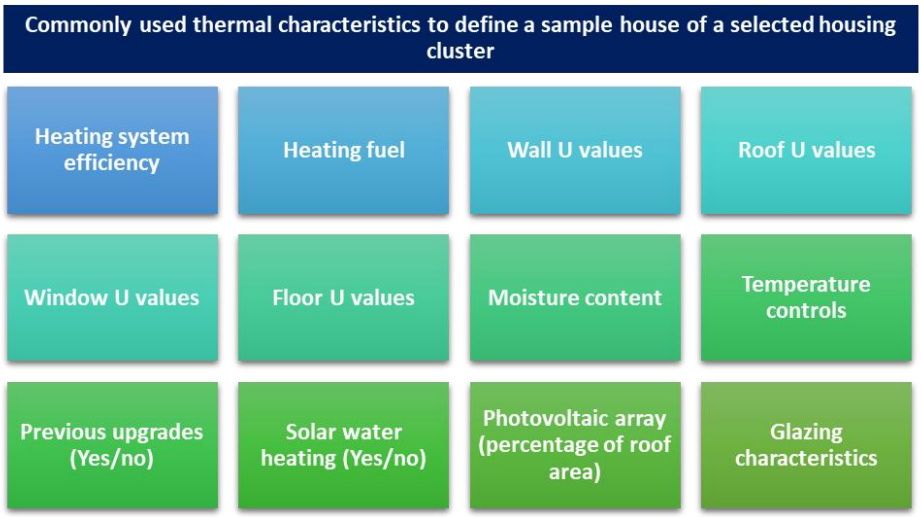


Figure 16: Thermal characteristics of a sample house

Ben, Hui et al. (2020) explain that the significance of occupant behaviour in influencing the effectiveness of energy retrofit has been widely recognised. The size of this effect may be large, impacting on energy usage by a factor of two or more. [6,12-14]. Researchers suggest that a better incorporation of the home user behaviour in the energy calculations can result in a more reliable model. It is also understood that the energy calculations and predications are a complex procedure. A simple end user profile selected can alter the energy calculation model to a larger extent resulting in huge difference in the actual and predicted values [15]. There are various studies that are carried out to identify the key features of user behaviour. These studies all aim at understanding and identifying better solutions for energy demand reduction. Intensive scientific research has also been carried out to identify the difference between the energy demand among different user profiles [16]. Dodoo et al. [17] found that the comfortable indoor temperatures affected the energy consumption in a large scale. Therefore, addressing behavioural variations in retrofits is crucial for achieving the required results.

The household characteristics of a residential house are defined by the researchers [20] by no. of inhabitants like single / couple / single with children / couple with children / family with grandparents; employment status like full-time, part-time, retired; age of the inhabitants & different levels of income. The average energy use of these inhabitants is found out to be for heating, cooling and lighting spaces, for heating water used in the kitchen or/and bathroom, washing/drying of clothes and operation of appliances. [21][22] Each inhabitant will show different patterns of behaviours in the usage of energy. One can be active spender, conscious occupier and so on as in figure 17 [23].

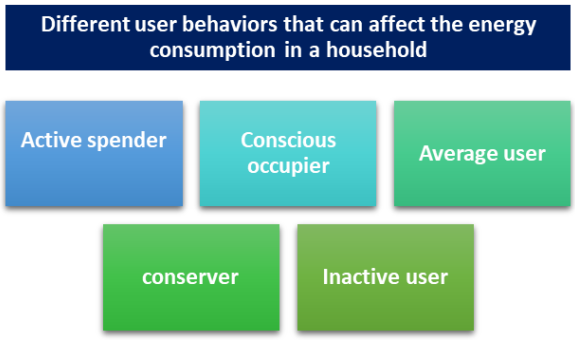


Figure 17: User behaviours that affect the energy consumption in a household

Research conducted in the Netherlands and also worldwide suggests the importance of renovation of buildings over their demolition for the realisation of the goals in the climate agreement. Renovations are identified to help in cost and time reduction, reuse of the existing architecture and protection of present communities [18][24]. Renovations can be divided into energy related or non-energy related renovations. Energy related renovations include works that are carried out in a house to reduce its energy consumption. Renovation can include installation of a new system / building element into the household or its replacement. Energy related savings are also divided based on the percentage of energy savings achieved for the household. Energy saving <3% is categorized as below threshold renovation, light renovations are those with energy saving 3% ≤ 30%, medium renovations are those with energy saving 30% ≤ 60% and deep renovations are those with energy saving >60% [4]. The following figure 18 shows few examples of the renovations that are commonly applied on households.

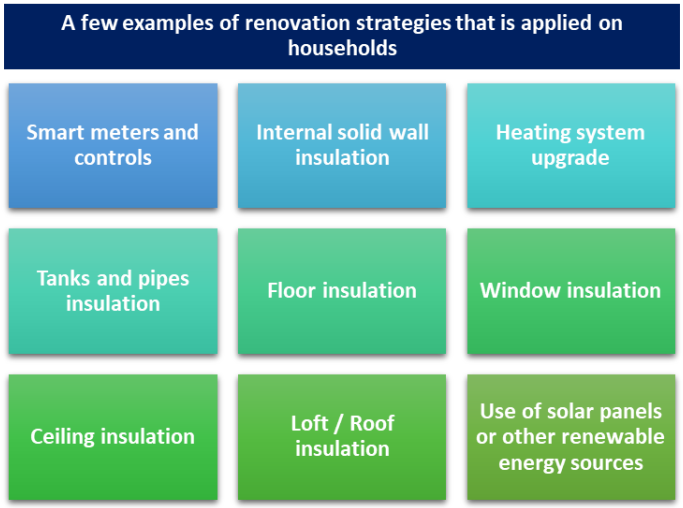


Figure 18: Renovation strategy examples used to apply on households

4.1.2 Dutch housing classification system

Figure 19: Beautiful yet wide varieties of typologies of houses in the Netherlands, each having their own unique properties.

"Voorbeeldwoningen Bestaande Bouw 2007" (En: Dwelling examples existing buildings 2007) developed by the former SenterNovem (now called Agentschap NL, the Netherlands) explained about the general classification of the Dutch housing stock. A statistical analysis shows that most row houses are built in the period 1975-1991 in the Netherlands as shown in Table 3. [8]

Table 3:Classification of Dutch housing stock as per AgentschapNL

	Detached Houses		Semidetached House		Row house		Duplex/Maisonette		Gallery house		Porch house		Apartment houses (other	
	No.of houses	% of Dutch housing stock	No.of houses	% of Dutch housing stock	No.of houses	% of Dutch housing stock	No.of houses	% of Dutch housing stock	No.of houses	% of Dutch housing stock	No.of houses	% of Dutch housing stock	No.of houses	% of Dutch housing stock
Built up to 1945					523.000	7.7					256.000	3.8		
Built in the period 1946-1964	441.000	6.5	285.000	4.2	478.000	7	226.000	3.3	69.000	1	267.000	3.9	99.000	1.5
Built in the period 1965-1974	119.000	1.8	142.000	2.1	606.000	9	22.000	0.3	174.000	2.6	112.000	1.7	125.000	1.8
Built in the period 1975-1991	221.000	3.3	224.000	3.3	879.000	12.9	94.000	1.4	109.000	1.6	142.000	2.1	125.000	1.8
Built in the period 1992-2005	178.000	2.6	173.000	2.6	353.000	5.2	40.000	0.6	113.000	1.7	70.000	1	136.000	2

The general classification is by the construction year with a year band of 10 to 15 years. Under each classification, a reference building is developed and the required details for the energy consumption, construction details, other geometric details are also given. The reference dwellings developed are intended both for policy advice purposes and building stock management. These dwellings can be assumed to be the representations of the whole group of houses under that respective typology. This was developed for the conduction of energy analyses of the groups of the houses. Following this approach, implications of current and future policy measures and regulations can be analyzed in terms of their energy savings, CO2 reduction potential and the related financial costs and benefits. A renovation strategy that is suitable for the reference building can be designed and can be applied to the rest of the houses as an optimal renovation strategy.

The housing typology in the Netherlands is namely as follows (Source: AgentschapNL):

1. Single family houses:
   a. Detached houses
   b. Semidetached houses
   c. Row houses
2. Multifamily houses:
   a. Duplex/Maisonette
   b. Gallery houses
   c. Porch houses
3. Apartment houses

In the literature review, similar methodologies of finding a representative house for a housing typology are found to identify the best appropriate renovation strategy and are suggested to be applied to the other houses belonging to the same typology having very similar characteristics.

4.1.3 Renovation of Dutch housing stock

As discussed in the previous sections, the Dutch climate agreement has set goals to accomplish a built environment that emits zero carbon by the year 2050. This increases the importance and immediate necessity of renovation of Dutch houses in a large scale. This can be done by designing housing clusters of the Dutch housing stock, thus increasing the demand and thereby motivating the renovation industry in standardization and industrialization. There are various pilot projects proceeding and completed in the Netherlands to serve the purpose of improving the energy efficiency of the Dutch buildings.

According to the results from the literature review in [25], the term “renovation” has been used by researchers to describe a wide variety of improvements to an existing building or group of buildings. From the literature review, it is understood that there are different types of renovation strategies which may (not) include the improvement in energy performance. In case of improving energy performance, there are various options from installation of Renewable energy sources (RES) to replacing the building elements. The refurbishment of a building façade (i.e. walls and windows) provides a different energy saving level compared to the retrofit of the overall building envelope and systems (heating, ventilation and air conditioning - HVAC, lighting, etc) [26]. The energy performance of a building can be improved by the implementation of a single measure, such as a new heating system or roof insulation. Such interventions are referred to as “small retrofit” or “minor renovation”. Typically, energy savings of up to 30% might be expected by the application of one to three implemented measures. Many discussions have risen around the meaning and the definition of "major", “deep” and “NZEBs” renovations [25].

The European Parliament reported the following definition: “***deep renovation means a refurbishment that reduces both the delivered and the final energy consumption of a building by at least 60% compared with the pre-renovation levels***” [6].

NZEBs renovation always includes technologies with very high efficiency by the usage of renewable energy production [23]. There can be an improvement in the energy performance by the use of low energy technologies (e.g. insulation, use of sunlight, high-efficiency Heating and cooling system,

natural ventilation) while RES include use of solar energy, wind energy, biomass, geothermal energy and also energy storage in the water bodies (e.g. Aquifer thermal energy storage - ATES system). A ranking of the preferred application of different renewable supply side options are also proposed by researchers [24] [27].

In the Dutch market, some of the new concepts, which are not discussed before in this report, that are applied for the housing renovations are the Zero Energy, Fossil Free, Carbon Neutral or "Nul-op-de-Meter" ("Net zero energy") and also the "Stroomversnelling program". Despite the presence of these programs, there is still need for better innovative concepts to accelerate the renovation rate in Dutch housing sector [28].

4.1.3 Drivers & barriers to Building renovation

Under the renovation topic, a main important area where the researchers have carried out prominent study is about finding the list of drivers and barriers to renovation. These drivers and barriers are found out taking into account various perspectives like, the end user, home owner, housing corporations, energy supplier, contractor, government and so on [29].

Drivers [28-30]

Homeowner – Most important incentive for the home owner to carry out renovation is the potential cost saving on the energy bills. They also believe that renovating their homes can increase the indoor comfort, improve ventilation & also increase the house re-sale value. Renovations are also done as a measure to protect the environment. Housing corporations wanting to do the renovation can be a driving force for the end users to renovate their homes.

Companies / supply side – Large scale renovation opens up the door for more profitability for the companies under renovation industries. It creates a new market where new innovative products can be produced. This leads to productivity and employment.

Barriers [5][7][22-26]

Homeowner - Lack of technical expertise among the housing corporations and the homeowners regarding the benefits of renovations and the impact of built environment energy usage on the environment leading to global warming. Lack of data and low-quality data– details regarding the housing stock. The complexity in the area to be renovated and the corresponding large effort required for modelling. Clients are afraid that the improvements in energy efficiency cause risks for the overall building performance. Owners being reluctant to borrow funds for energy renovation purpose is also common.

Companies / supply side - Lack of technical knowledge and lack of skilled workers among many solution providers who continue to follow the traditional methods of renovation or demolishment. Refurbishment concepts of a sustainable building renovation are missing. There are no actors who would be able to offer integrated solution. Lack of confidence also prevail among the investors.

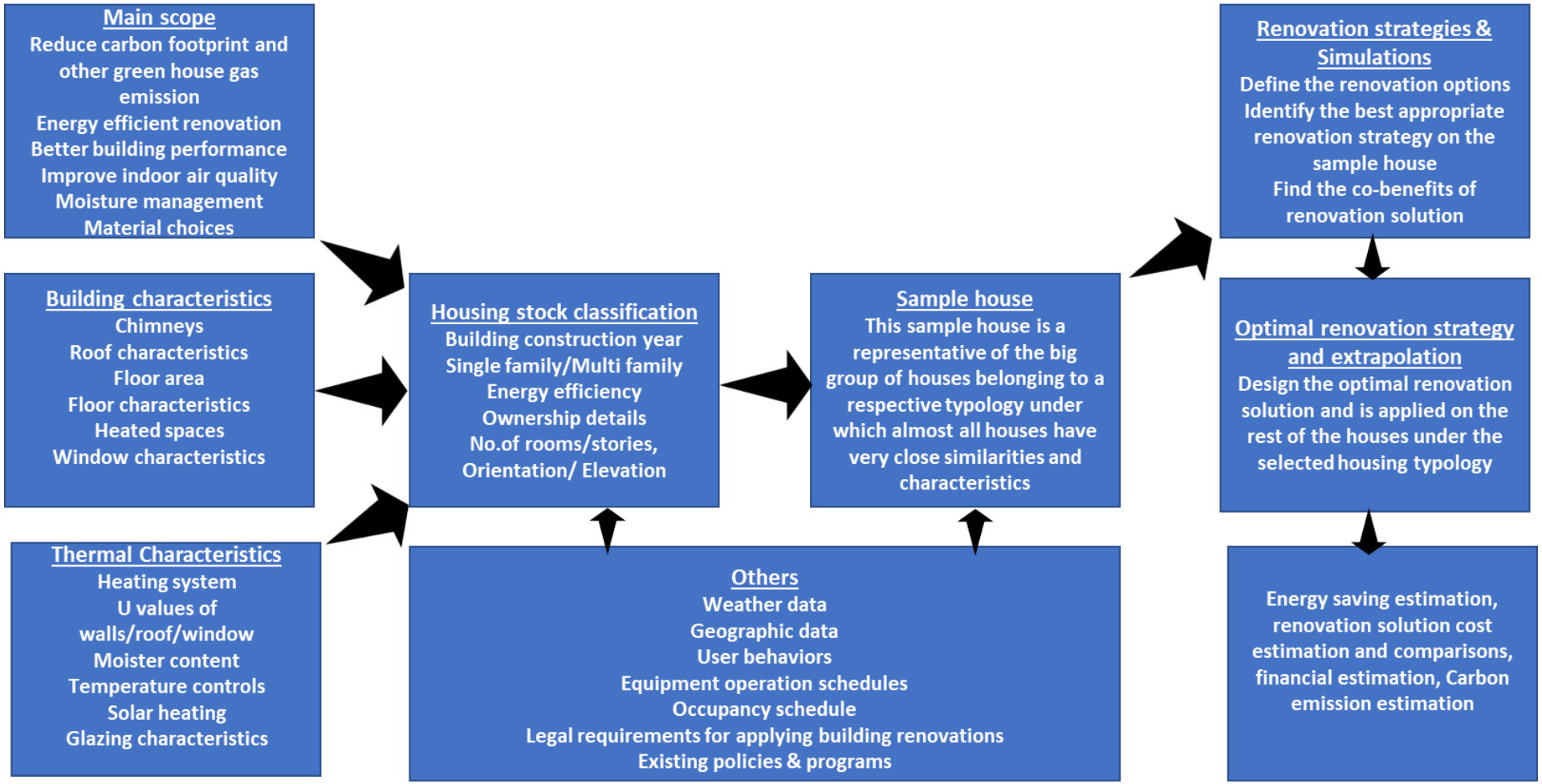


Figure 20: A flowchart of a typical framework of housing classification system and find an optimal renovation strategy

4.2 Analysis of housing clustering methods from the analysis of online survey responses

4.2.1 Housing classification system - analysis

As outlined in the introduction, for the purpose of standardization and industrialization, a housing classification system will be designed by which dwellings will be clustered and tendered. In the climate agreement, it was envisioned as part of the Renovatieversneller that large-scale tendering of housing renovation clusters would be organized on a national scale. **More than 75% of the respondents agreed the following derived requirements that this housing classification system has to meet to promote standardization and industrialization**.

1. Large-scale tendering of housing renovation clusters will promote standardization and industrialization and help accelerate the renovation process to 300.000 homes per year
2. Large-scale tendering of housing renovation clusters should be organized on a national platform, for consistency in procedures (e.g. standardized formats and requirements for quality assurance and performance guarantees) that all parties must comply with.
3. There is a strong need for the dwellings within a cluster to have similar characteristics for the purpose of standardization and industrialization.
4. There is a strong need for the requested renovation solutions to be similar.

<u>Barriers identified in the demand side (houses) from 14 respondents – Score means the number of people who voted for the particular option versus the total number of respondents</u>

Insufficient capital for the housing corporations, Vve's or homeowners (Score: 10/14)

Not enough support from the government / No Uniformity in renovation specifications / No Uniformity in demand - no similar or uniform housing properties / Constant and predictable demand for renovation of houses (Score: 7/14)

Sufficient volume (number of houses to be renovated) / Renovation work creating nuisance to the inhabitants (Score: 6/14)

Other barriers pointed out by the respondents in the comment section were the following:

1. Unpredictable policies
2. New concepts are considered as risks and fears.

Around 70 % of the companies neither provides a renovation solution with guaranteed energy performance, nor includes a guaranteed internal comfort level for the users, such as room temperature, air quality.

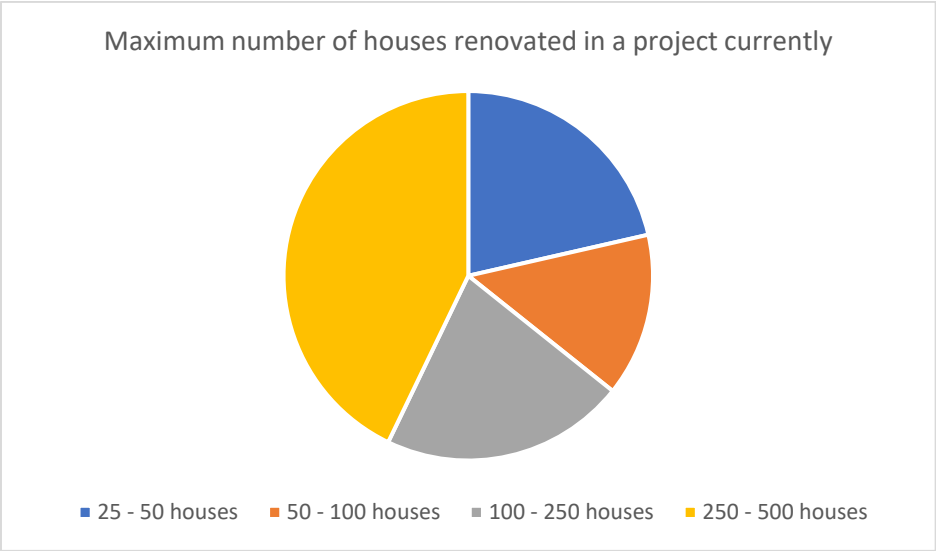


Figure 21: Maximum number of houses that can be renovated in a project as per the current production capacity of the companies responded in the survey

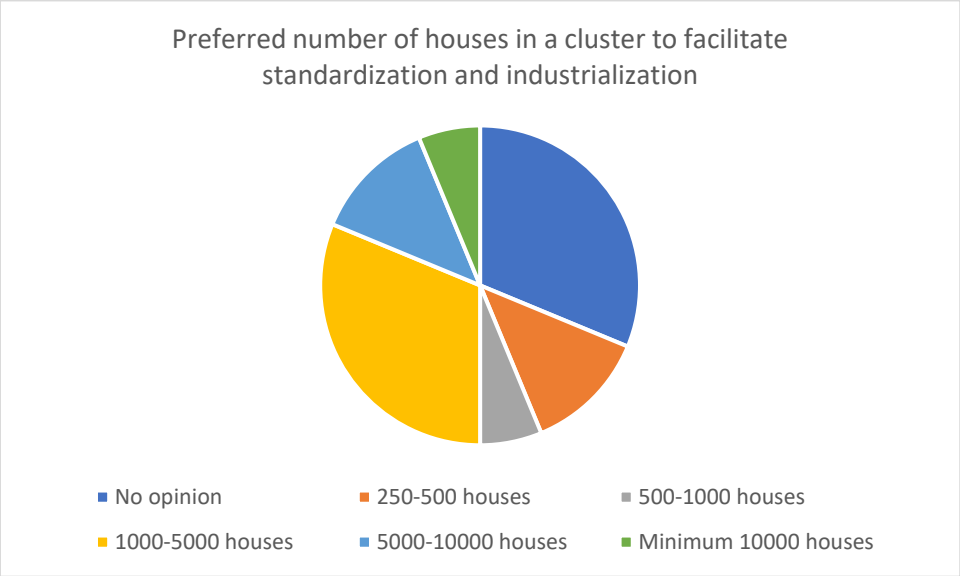


Figure 22: Desired number of houses to be in a cluster for the companies to profit them from industrialized production units.

Though many companies do renovate 250-500 houses in a current project (see Fig. 19), majority of the companies responded that they can accommodate only less than 250 houses. This makes standardisation and industrialization a big challenge in the renovation industry.

In the online survey, the respondents were asked to indicate their preferred number of houses in a cluster (see Fig. 20). The question was framed to ask the future vision of companies, where a housing classification system is designed and the companies have invested in higher levels of industrialization, what will be their ideal number of expected houses in a cluster. Responses include a large number of

companies that chose to not give an opinion. When not taking those into account, the survey indicates a preference for the cluster range of 1000-5000 houses.

In the Renovatieversneller, it was envisioned that dwellings would be clustered to be 'similar', in order to create a demand that can be standardized. However, it is currently unclear which dwellings can be in the same cluster (for the purposes of standardization and industrialization), and which can't. Table 6 shows the opinion of the supply side about the acceptable and non-acceptable variations in a cluster.

Table 4: Companies responses of their preferred characteristics of a housing cluster

Options provided in the survey	**Majority (70%) of the responses of the supply side**
Different layout of the windows in the façade	**Definitely should be in the same cluster**
Different roof shape	**Definitely should not be in the same cluster**
Different additions (dormer-window, extension of the ground floor, etc.)	**Definitely should be in the same cluster**
One in-between and other corner-house (both row house)	**Definitely should be in the same cluster**
One row house and other detached house (difference in typology	**Definitely should not be in the same cluster**
One row house and other apartment (difference in typology)	**Definitely should not be in the same cluster**
Different floor construction type	**Definitely should not be in the same cluster**
Different roof construction type	**Definitely should not be in the same cluster**
Different wall construction type	**Okay if present or not in the same cluster**
Different cavity depth	**Okay if present or not in the same cluster**
Different existing insulation level	**Okay if present or not in the same cluster**
Different desired renovation solution: different insulation levels	**Definitely should not be in the same cluster**
Different desired renovation solution: different HVAC-system	**Definitely should not be in the same cluster**
Different desired renovation solution: different finishes	**Okay if present or not in the same cluster**
Different neighbourhood/city	**Definitely should be in the same cluster**
Different region/province	**Definitely should be in the same cluster**
Different ownership (housing corporations / VVE / private homeowners)	**Definitely should be in the same cluster**

From the analysis of the survey, Table 6 gives a clear insight on how a cluster can be created taking into consideration the preferences of the companies. The analysis shows that since most of the companies have their renovation works spread across the Netherlands, the geographical classification of houses are not required. The houses situated in different provinces and with different ownership can be designed to be in a cluster.

Furthermore, houses that have different roof shape (angled or terraced), roof construction type, floor construction, mix of different type of houses (like a row house and apartment in same cluster are not recommended) and different renovation strategies are not recommended to be in a same cluster. The housing clusters having an optimal renovation strategy will aid in large scale renovation of houses.

Elements that can be mass produced according the renovation industry are listed in Table 5.

Table 5: List of building elements that can be mass-produced

Building element	**Possibility of mass production**
Facades, Roof elements	High (70 %) possibility of mass production
Walls, Windows, doors, Bathroom fittings	Around (50 %) possibility of mass production with a high possibility of risk
Flooring panels, Kitchen modular components, Foundation elements & Fittings	Least possibility of mass production

4.2.2 Renovation time

In the survey, one of the questions was the number of days required to complete the whole house retrofit process of a single dwelling. From the figure 23, it is evident that the whole house renovation process can be carried out definitely in less than 10 days' time by 87 % of the respondents. It is also an important finding that 50 % of the responded companies can finish the renovation works in less than 5 days' time which makes it more convenient for the home user. But, as discussed in the literature review there are also new pilot renovation projects undertaken in the Netherlands that complete the work within a days' time.

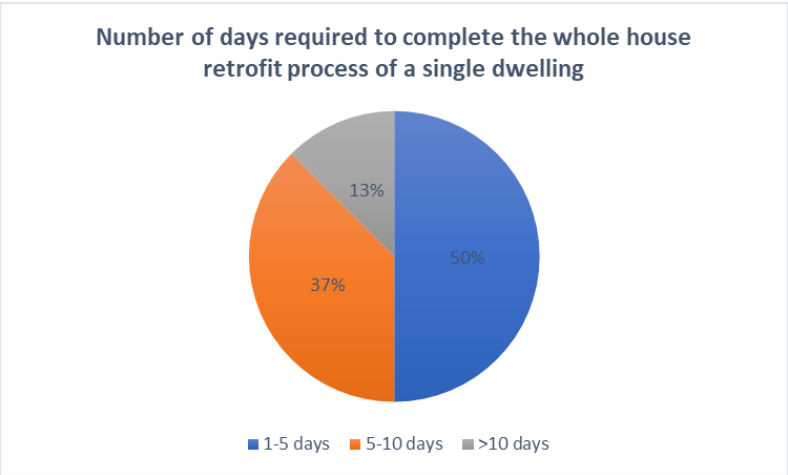


Figure 23: Pie chart representation of the number of days required for a single dwelling complete renovation

Comparison of results

Housing classification system

Systematic literature review	Vs	Online survey
Large group of researchers have mentioned the importance of a housing classification system for the energy analysis but not in the context of advancing standardization and industrialization by large scale housing renovations.	**Need for housing classification system**	Companies also supported the innovative idea of housing classification system consisting of houses with similar characteristics that is designed to create a large renovation market and promote standardization and industrialization.
In literature review, housing typologies are defined, and a sample house is selected for further analysis of the research purpose. The renovation solution designed for the sample house is applied to the whole typology selected.	**Housing typology & sample house**	Companies do not support the idea of sample houses since they experience difficulty in renovation execution even for similar housing typologies because of the differences between houses within the same typology.
Researchers have already discovered through statistical analysis that housing corporations are in authority of a large number of houses in the Netherlands.	**Housing corporations**	From the response analysis of the survey, it was clear that the housing corporations were the major clients in the renovation sector.
In the literature review, the characteristics considered for a housing typology is mostly related to energy calculations and carbon emission calculations. There is little emphasis on the characteristics of a housing classification that can aid in standardized products.	**Characteristics considered to design a housing classification system**	The online survey helped in finding out which characteristics of a house can be considered in designing a housing cluster that will help companies to advance in standardization and industrialization.
Government policies that help in the energy savings and carbon emissions are mentioned in various scientific papers	**Government incentives, policies & support**	The housing corporation & companies expect well defined support system from the government to design the housing classification system that would aid in large scale renovation works
For the sample house, the researchers have designed simulation models to identify the optimal renovation technique. Then it is applied to the rest of the houses in the typology.	**Similar renovation techniques**	Similar renovation techniques applied to a housing cluster would result in the possibility of mass production of optimal renovation products and thereby reducing the price.
In many scientific papers, emphasis is given to the user behavior considerations for energy calculations but little importance is given on the end user opinions on the renovation options and their preferences.	**End – user considerations**	In the renovation industry, the cultural relationship between the client and the provider continue where customization is given importance rather than standardized products.

5. Tendering mechanisms

5.1 Analysis of tendering mechanism through literature review

5.1.1 Tendering strategies in Dutch housing market

"*Various industries and entrepreneurs define Procurement as the following: Procurement is the acquisition of products and services, specifically for a business purpose. It is a process that starts from identifying the requirements of the goods and services. These activities can involve the process of setting up a process, collecting bids, selecting vendors, negotiating contracts, often via a tendering or competitive bidding process*."

"*Tendering: Tendering is limited to the process within procurement of going to the external market with your need specification with the intent to collect, analyse and nominate bids. Researchers have identified the following definition and is commonly used among construction industry. An invitation to tender (ITT, known as a call for bids or a request for tenders) is a formal, structured procedure for generating competing offers from different potential suppliers or contractors looking to obtain an award of business activity in works, supply, or service contracts" (Consular Reports: Commerce, manufactures, Issues 164-167)* [32].

The Dutch housing associations are responsible for the periodic & planned maintenance of the houses. However, the tenants are allowed to perform some renovations such as replacements of fittings, windows, doors and certain installations [33]. As the above definition explains, the procurement process begins with the identification of requirements and its specifications, then the suppliers are selected. The next step after finalizing the suppliers is contract agreement signing. After the contract is accepted, the materials or services are ordered. The next steps are expediting and evaluation. *"The definition for expediting commonly used by supply chain industry is the following : Expediting is a concept in purchasing and project management for securing the quality and timely delivery of goods and components."* The last step in procurement is follow-up and evaluation of the service or product delivered.

"For a large-scale renovation of housing classification system in the Netherlands for the promotion of standardization and industrialization of supply side, a possible solution can be introduction of a tendering mechanism that bridges an innovative contract between the homeowners and the service / product suppliers"

5.1.2 Tendering procedures followed by Renovatieversneller & Energiesprong

The tendering scheme followed by the Renovation Accelerator was included to promote the most promising innovative projects. Within this scheme, large landlords and innovative providers can carry out standardized renovations on a large scale for the first time. The Ministry of the Interior and Kingdom Relations opens the Renovation Accelerator subsidy scheme annually in a series of four subsidy tenders from 2020 to 2025. Five million euros per year has been made available for the support program (30 million in total) [9].

"The Energiesprong market development team developed a solution based around a highly innovative business model involving a net-zero energy performance contract, an integrated and industrialised supply chain, a single customer interface, a financial model based on the performance contract, and co-ordinated governance of these elements. Thus, the market development team acted as an innovation intermediary combining different actors and components to develop an innovative new business model" [34].

In the Energiesprong model, customers are offered a complete whole-house retrofit, based on guaranteed net-zero energy consumption which is rarely provided in the renovation industry. This involves off site manufactured, insulated façades and modules integrated with renewable heat sources and PV panels. The contractor offers a 30-year energy performance guarantee for a net-zero annual energy consumption that can be very beneficial to the end-user. This also provides a guaranteed internal temperature of 21°C in living spaces, a set allowance of hot water and electricity; analogous to a mobile phone contract with usage limits providing a comfortable living space for the home users. The aim is also to reduce the duration of the retrofit to under one week using offsite manufacturing and modularisation. The model does not prescribe any specific measures but rather the performance outcome, following a performance-based procurement approach [6][35].

The Energiesprong business model gives importance to performance more than technical solutions. It also emphasises on the delivery of net-zero energy solution by providing a one-stop solution from a single supplier. The Energiesprong model is also driving a move to industrialisation and offsite manufacturing with integrated energy modules (heat pump, ventilation unit, solar inverter) that can be miniaturised, and mass produced. It also shows that the renovation solutions can be made cheaper along with achieving economies of scale for the provider and also the installation time to one single day in the Netherlands. The Energiesprong model therefore adopts a performance-based approach to procurement [36].

5.1.3 Tendering mechanism according to researchers

The use of integrated contracts in the Dutch construction sector has increased in recent years. Integrated contracts facilitate a much more effective process than traditional delivery methods, leading to reduced cost and time and higher quality. Initially, this type of contracts were only used for large and complex infrastructure projects and new buildings. In the last few years, they have been used also in the social housing sector for renovation projects, giving positive project outcomes. In these projects, the supply-side works together as a team formed by an architect, consultants and construction companies; commonly known as a consortium to develop the most innovative, reduced cost and high quality products.

In fact, the use of these contracts in renovation had its special momentum in 2008, when the shared aim of the national government and social housing organisations (SHOs) for reducing the energy consumption of their housing stock was expressed in the "Covenant for energy savings". In the covenant it is declared an aim for upgrading to a B label the Dutch social housing stock or a least to upgrade it two levels higher than its current status. In the Netherlands, social housing accounted for 32% of the total national dwelling stock in 2008 [37].

The selection and award criteria used in tendering and contracting, the type of specifications (descriptive or performance-based) and the contract's volume can change the relation among actors involved in the renovation process and can even change the structure of the process. Even though European public tendering rules promote the use of award criteria, currently numerous SHOs are still awarding the contracts by selecting the lowest bid, without valuing the quality of the services offered. Moreover, the tenders and contracts mainly use descriptive specifications. This reduces the opportunities for innovation by the construction companies and makes it difficult to define responsibilities in case of mistakes [38]. In order to set up a tendering strategy, prices of the renovation should be estimated. In 1956, Lawrence Friedman laid the foundation for tendering theory in "A Competitive Bidding Strategy" ([39].

"The public procurement directive defines the competitive dialogue procedure as a procedure in which any economic operator may request to participate and whereby the contracting authority conducts a dialogue with the candidate admitted to that procedure, with the aim of developing one or more suitable alternatives capable of meeting its requirements, and on the basis of which the candidates chosen are invited to tender" [39]. Although it is a useful tender method that housing cooperatives can use, there is another procedure that might be more useful for housing cooperatives for more innovation partnerships. "*An innovation partnership is a new procedure in the European directives 2014/24/EU and in the Aanbestedingswet 2012 (tendering law in Dutch). This procedure can be used for the procurement of products and services which are not available at the market or are not on the desired quality level yet" . This procedure is explained in Innovatiepartnerschap, 2017.* If the solution is not yet known either for the client (housing corporations) nor the supply side, then they can choose this procedure as an option. The contract ensures the degree of innovation and the betterment of solution according to its performance in the market. If the large scale renovation market is yet to be developed, these innovative partnerships can be helpful between the housing corporations and renovation industry. Though the one-stop single solution is not available yet for the large scale renovation, an innovative partnership contract can be a start for it.

5.2 Analysis tendering mechanism from the analysis of online survey responses

In the Renovatieversneller, it was envisioned that dwellings would be tendered on a national platform, where contractors and consortia would 'bid' on the large-scale renovation clusters. The following are the various levels of information of the dwellings that the companies unanimously voted as important in the survey conducted for this study in order to be more able to participate in the tendering of a large-scale renovation cluster, and to provide a quote (assuming that the renovation requirements are clearly specified).

- BAG-data (typology + construction year)
- Basic description of key characteristics (glass surface area, floor surface area, roof shape, wall/floor/roof construction type, etc.)
- Construction drawings
- 3D-scan of the exterior
- 3D-scan of the interior

- Simplified energy label documentation
- Comprehensive energy label documentation

Other information required that were pointed out in the survey comment section, were the following:

- *"Existing installation concept"*
- *"Building up, dormers etc. Presence of asbestos. Quality / presence of delivery systems CV. Experience shows that certain constructions (foundations, floors, building walls, inner cavity blades, roofs and roof base) are executed differently than the building drawings. These points must be known or there should be time to examine them."*
- *"Approvals that have already been issued by the municipality/government in terms of use materials/view of the buildings (window frames/roofs etc.). "*

Following table shows certain criteria and its importance in the tendering evaluation process.

Medium importance	**Medium to great importance**	**Great importance**
Time per dwelling	Cost	Quality of renovation solution
Industrialization		Communication with inhabitants
Environmental impact of the construction works		Innovation of process and products

25 % survey responses showed that the tendering process should be open to all as in the graphical representation. But it is also prominent that close to 50 %, thinks it should be invited to 2-3 or 5-10. So quite a lot of people think that tendering should be on invitation for a small group.

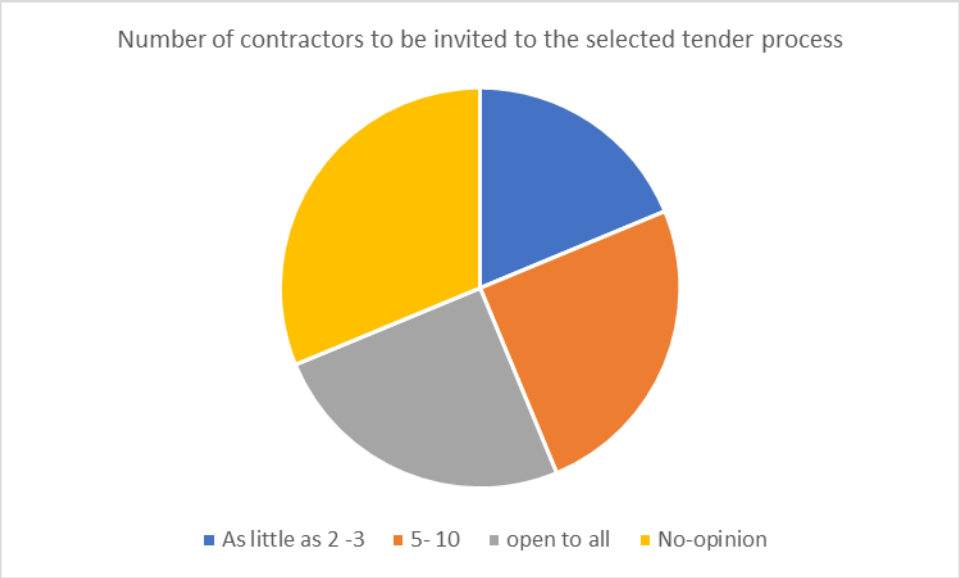


Figure 24: Number of contractors to be invited to a selected tendering process

Tendering Mechanism: A bridge connecting Demand & Supply

Supply side

A guaranteed energy saving renovation strategy

With less inconvenience to the end user

Constant improvement in the standardization of their products and the industrialization techniques followed within their production line

Demand side

The demand consists of housing corporations, VVE's and private homeowners

An innovative method of housing classification must be designed in which each cluster of houses consists of houses having similar characteristics.

An optimal renovation strategy is designed for each typology which can be applied to the houses under the same typology

This enables the companies/supply side to standardize the products and the production process leading to mass customization also taking into consideration the client needs.

Tendering Mechanism

A tendering mechanism bridges the demand side and the supply side thus promoting standardization and industrialization.

The tender framework should clearly define the scope and requirements of a renovation strategy

A promised incremental demand should be constantly monitored as a part of the tender mechanism

The levels of industrialization of the companies should also be checked according to the framework of the tendering mechanism

The degree of innovation should be an important criterion in a selection criterion

5.3 Comparison of results – tendering mechanism

Comparison of results

Tendering Mechanism

Systematic literature review	Vs	Online survey
The concept of tendering mechanism for a large-scale renovation market is a break-through innovation were there is lot of scope for research work.	**Application in large scale housing renovation market**	A tendering mechanism that ensures a structured, homogeneous, bundled and (multi-year) predictable growing demand for renovation works is highly welcomed by the companies.
The purpose of a tendering mechanism according to literature review was to identify the best bid according to cost analysis.	**Purpose**	The tendering mechanism should ensure the importance and continuous evaluation of innovation and technology in a project other than the cost analysis.
The information available in the requirements are not clear in most the cases and the researchers also suggest that a well-defined requirement list in the tender will positively affect the whole tendering process.	**Information available to quote a tender**	Requirements should be clear and more information regarding the houses to be renovated should be available for helping the companies to provide a more accurate quote.
The selection criteria used in tendering, the type of specifications and the contract's volume can change the relation among actors involved in the renovation process and can even change the structure of the process	**Contractor's volume in a tender**	Most of respondents responded that the number of contractors should be less than 10 who are invited to a selected tendering process

5.4 Successful large-scale renovation tendering projects in the Netherlands

"*The Guidelines on State aid for environmental protection and energy 2014-2020 indicate an evolution towards tendering (competitive bidding) as a reference system for public support allocation to renewable generators from 2017. The proper design of tenders is of utmost importance to sustain wind energy's growth path."* [40]

Designing a tendering mechanism for the large scale housing renovations is one of the agenda items in this project work. For this purpose, other successful tendering mechanisms carried out for large scale works are identified and studied. One such project is the large scale off-shore wind mill projects which used the aid of an innovative tendering mechanism for achieving cost reduction in wind energy production. According to this project, there were large scale investments involved because of which there was a decrease in cost and also it ensured the needlessness of other support mechanisms like subsidies.

There are also studies that aim at finding the offshore wind energy development without the use of any subsidies. This is done by finding the best method to design a tendering mechanism. Studies also suggest that the well detailed design of a tendering mechanism can aid in the cost reduction and finding innovation solutions [41]. Certain main characteristics of a tendering mechanism from successful offshore wind projects are wind capacity, date of auctions, capacity of wind turbines, wind farms awarded, average bid, minimum bid, one-sided/two sided, time duration in years, other costs and inflation adjustments. This encourages to identify the important characteristics of a tendering mechanism in large scale housing renovation projects.

A report generated by Navigant company and TU/e on Renovatieversneller suggests that the tendering mechanism that was successful for the large scale wind farm projects can be used as a reference to design the tendering mechanism for large scale renovation of the housing sector in the Netherlands [42]. It is also highlighted that the workability of such a concept is possible only if it can be adapted to the complexity of the built environment.

6. Standardization and industrialization

6.1 Required information provision for the supply side to advance in standardization and industrialization through literature review

During upscaling and industrialization, sufficient information must be available about the buildings to be made more sustainable. Majority of researchers support the fact that BIM (Building information modelling) can significantly reduce costs by better time management and automation. This lowers the risk of failure costs [9].

6.1.1 Definition of Industrialization

"According to Heijmans, industrialization is the shift in production processes from manual labor to mechanical labor. R. Borjeghaleh (2016) explained that industrialization of building could make great contributions to the housing demand were prefabrication and modular construction in factories and then assembling them within the job-site could increase the quality of project implementation and reduce the project time". [43]

Industrialized construction has been described as consisting of a framework of eight different areas which include both processes and technical systems as well as support mechanisms for these (Lessing, 2006):

- Planning and control of the processes
- Developed technical systems
- Off-site manufacture
- Long-term relations
- Logistics integrated in the building process
- Customer focus
- Use of ICT
- Performance measurement and re-use of experiences

"Researchers and scientists define industrialized manufacturing as a process that aims to improve production by replacing the traditional, artisan manufacturing process with standardized, machine-based manufacturing processes that deliver a consistently affordable, high-quality product."

"Industrialization involves the extensive use of large format prefabricated factory finished elements and the conversion of production into a mechanized and continuous flow process of assembling and installing buildings and structures made of prefabricated assemblies and parts."

6.1.2 Levels of Industrialization

Any method better than the **traditional renovation techniques** is considered as an improvement in the level of industrialization. The traditional renovation techniques involve construction and building the renovation products at the site using manual labour which is not time efficient and involves inconveniences to the end user and high costs. The problems faced in the traditional techniques can be solved by introducing better industrialization techniques such as the following.

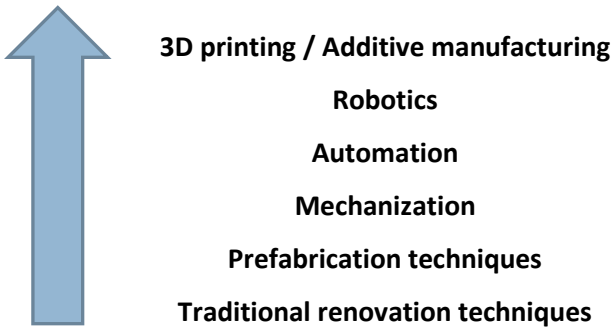
Prefabrication techniques - Prefabrication means that building components are produced in a weather protected factory very similar to those done on a traditional construction site by semi-skilled workers with specialized tools and equipment, using the same materials and processes on site. By adopting Design for Manufacturing and Assembly (DfMA), the transparency and efficiency of the entire construction project is increased. The production of prefabricated building components is controlled at the factory level with strict quality controls. Prefabricated building components are manufactured on schedule and delivered just-in-time to construction sites for assembly, creating a seamless construction process.

Mechanization - Mechanization is the term used whenever machines are involved in the work, such as using the most advanced technological power tools, mobile cranes and other machines. Prefabrication usually involves mechanization. For example, to lift the volumetric or 3D modular units, a mobile crane is used to lift the 3D modular units.

Automation - Automation is the process whereby the tasks of employees are completely taken over by machines. Although automation results in a reduction in labor requirements, it still requires industrial engineers, programmers and supervisors to run the machine.

Robotics - Emerging robotic technologies in use in the construction industry today include demolition robots, 3D printing robots, robotic total stations, robbers and laser scanners, robotic drones, masonry robots, welding robots, exoskeletons, forklift robots, roadwork robots, and humanoids.

3D printing / Additive manufacturing - At the forefront of digital fabrication is Additive Manufacturing (AM), better known as 3D printing, which produces objects by building structures from tiny deposits of materials in layers. The construction industry has begun to explore AM as an emerging construction technology. With AM it is possible to go directly from a 3D model of an object to a finished product at the touch of a button and one machine, using a wide variety of materials such as steel, glass, ceramic, polymer, concrete and more.



6.1.3 Mass customization

A combination of advances in information and technology like robotics and other advanced machinery is making the production increasingly possible to mass customize and to rapidly respond to consumers with customized products at mass production prices [44]. Therefore, mass customization covered most of industries in the world economy and had a great feedback from the customers, especially in prefabricated building construction industry.

"Researchers define mass customization as a production strategy that focuses on offering customized products, at a low cost. Exploiting principles in mass customization, like standardization of modules, configuration and flexible production, makes it possible using a variety of tools to composing and producing customized products for commercializing at similar conditions as serial produced standard products".[45]

6.2 Required information provision on the supply side for standardization and industrialization from the analysis of online survey responses

6.2.1 Industrialisation according to 20 respondents

When the respondents were asked to explain about the industrialization techniques followed in their companies, it was clear from the comment section that many of the companies followed prefabrication techniques for the building of the components in combination with on-site assembly. Unanimously, they all agreed that industrialization techniques are important, yet they also raise the issue that it is very difficult to design standardised modules and components. It is argued by respondents also that it is a challenge to convince the company to invest in industrialization when a large-scale renovation market does not exist yet.

3D printing / Additive manufacturing

Robotics

Automation

Mechanization

Prefabrication techniques

Traditional renovation techniques

The renovation works are project-based and most of the time customized. This reduces the probability of arriving at standardized products or processes. In general, majority (around 75-80%) of the companies still followed traditional renovation techniques, a much lower percentage (around 15-20%) followed pre-fabrication techniques and very few (1-5%) followed higher levels of industrialization. The reason why companies wait to invest in industrialization is because the renovation market is very small and fragmented. The renovation solutions that are currently offered bear very high costs, making sustainability least affordable. An increase in demand for the renovation works will result in more standardised products and industrialization of the renovation industry.

6.2.2 Pre-conditions for Industrialisation according to 17 respondents

Certain preconditions are required from the supply side (companies that offer renovation solutions). The ranking of the pre-conditions (provided as options) as per the respondents are as below ranked from most important to least important. The deficiency in capital to invest in industrialization ranked the most important after analysing 17 responses.

Sufficient capital must be available to invest (13/17)
There must be sufficient knowledge, expertise and skills among employees (11/17)
Automation and control processes must be digitized (11/17)
Robots must become more available (from 3D printers to autonomous robots) (6/17)

"A very important comment read – "I work mainly in the renovation of existing homes. 4 houses in a block are often too different also due to individual requirements of residents to implement them as standard". The comment section for more pre-conditions of industrialization showed that the demand is in-consistent and the current projects focused more on the customer requirements."

6.2.3 Levels for Industrialisation

Out of 11 responses analysed, only one company responded that they currently do not pursue the traditional renovation techniques. Instead, they rely on prefabrication techniques, mechanization, automation and robotization.

Most of the responses support the use of traditional renovation techniques along with prefabrication techniques, mechanisation and automation, as can be seen in Fig. 21. There are very few companies where the higher levels of industrializations are used, such as 3D printing and use of robotics.

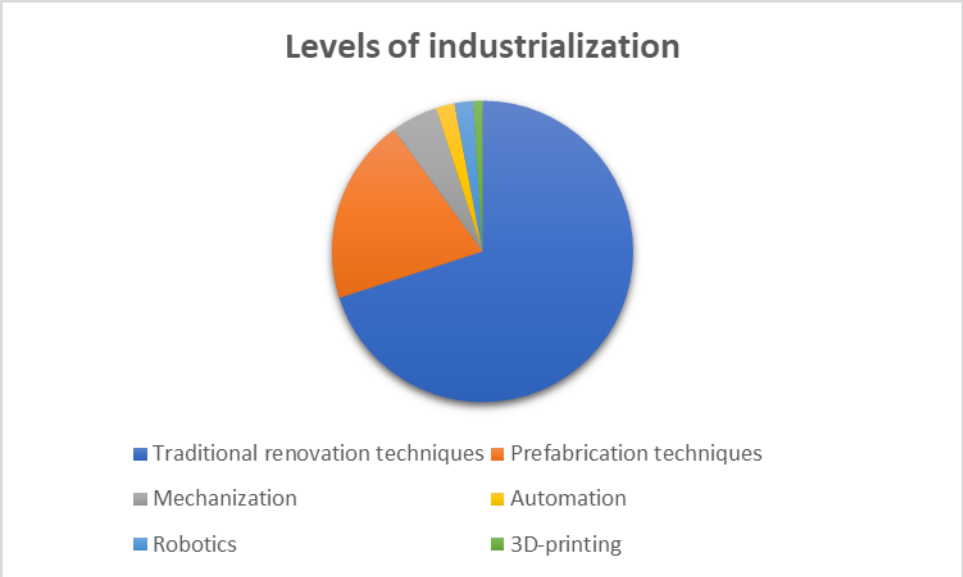


Figure 25: Levels of industrialization followed by the companies

Comparison of results

The required information for standardization and industrialization

Systematic literature review	Vs	Online survey
No researchers pointed out industrialization as scope of work in renovation projects though it is for new construction techniques	**Industrialization as scope of work**	Companies also find it very difficult to improve the scope of industrialization techniques to their renovation projects which is highly customized
Researchers have a clear definition that industrialization is process to improve production by replacing traditional techniques.	**Alignment on definition of Industrialization**	Companies also agree that industrialization is process to improve production by replacing their traditional renovation techniques.
In the literature review, the levels of industrialization are clearly defined and also show prefabricated modules are commonly adopted.	**Levels of industrialization**	More than 75% of the companies having renovation projects still follow traditional construction techniques
Little research has been conducted on the building elements that can be standardized under a renovation project.	**Standardization**	Companies from their experience and research explain the difficulty of standardizing elements because of the variations present in the houses
Researchers have listed certain preconditions of industrialization like availability of sufficient funds, skilled & experienced labor, automation and process control, 3D printers & autonomous robots.	**Pre-conditions of industrialization**	Companies agreed to all the preconditions of industrialization giving more importance to insufficient funds and foreseeing the risks involved while investing in industrialization for a large-scale renovation market that doesn't exist yet.

7. Conclusion

As discussed in the above chapters large scale renovation of the Dutch housing stock is inevitable and innovative solutions are required to develop this renovation market from a few hundred housing projects to 3.000.000 house renovations per year. The current deep renovation rate from <0.1% per year should be increased to 2.5 % - 3 % by the year 2030. The large scale renovation can be promoted by bundling of the demand by designing housing clusters that consist of similar characteristics. The housing clusters are to be designed in such a way that, when these clusters are tendered, it motivates the supply side to invest in standardisation and industrialization. From the online survey conducted as a part of this project work, more than 75% of the respondents agreed that this housing classification system along with a well-designed tendering mechanism will promote standardization and industrialization.

The respondents that participated in the survey included technical experts / consultants, project & process managers and business & economic analysts. A good mix of experienced (ranging from ≤5 to ≥ 30 years) professionals answered the questionnaire. 70% of them have their renovation projects spread across the Netherlands. 61% of the clients in a renovation project were housing corporations as also supported by the literature review. Important conclusions drawn from this project work under the main topics housing classification system, tendering mechanism and standardisation and industrialization are listed below:

<u>Housing classification system:</u>

- The housing classification system should consist of clusters of houses having a volume that is suitable and motivational for the companies to invest in industrialization. This means the number of houses in a cluster must be 1000-5000.
- According to the supply side, the houses situated in different provinces and with different ownership can be designed to be in a cluster.
- Houses that have different roof shape (angled or terraced), roof construction type, floor construction, mix of different type of houses (like a row house and apartment in same cluster are not recommended) and different renovation strategies are not recommended to be in a same cluster.
- In cluster, it doesn't matter if a middle house and a corner house of the same row houses are designed to be in a same cluster.
- Each housing cluster should be linked to a similar renovation strategy.

<u>Tendering mechanism:</u>

- A well designed tendering mechanism periodically evaluates and thereby improves the quality of renovation solution, improves the communication within the actors involved and promotes innovation of products and processes.
- The tendering mechanism consisting of the details of the houses such as the key geometrical details, BAG-data, construction drawings, 3D scan of exterior and interior and energy label documentations will be very useful for the companies to provide a more accurate quote for renovation works.

- Furthermore a tendering mechanism consisting of details regarding the previously executed renovation strategies like the insulation done previously, energy system installed, building elements changed or improved can also be an useful information for the companies participating in the tender. It is also good to have the municipality / government approvals obtained in the tender.
- Close to 50 % of the survey respondents thinks that in a tendering process, the number of participants invited should be 2-3 or 5-10. Also 25% of the respondents prefers the tender to be open to all.

Standardisation and industrialization:

- By industrializing the production lines of a renovation company by 70% using automation, 3D printing and robotics, mass production of façade and roof elements can be done in a large scale.
- The current renovation industry is project based and produces purely customised products as per the requirements and satisfaction of the clients. To substantiate that the online survey results showed that the traditional renovation techniques are highly used in renovation projects which is close to 75 %.
- In very few pilot renovation projects, more standardised façade elements are produced using sophisticated robots and 3d printing. Only less than 5 % of the renovation techniques are carried out using well advanced industrialised process like robotics, 3D printing and automation.

The overall generalised conclusion is depicted in a pictorial representation in the following page.

Standardization & industrialization for the renovation of large-scale housing clusters

Digital tender

01 RESEARCH WORK

More research work on the scope of standardization & industrialization for the large scale renovation works should be carried out.

02 KNOWLEDGE SHARING

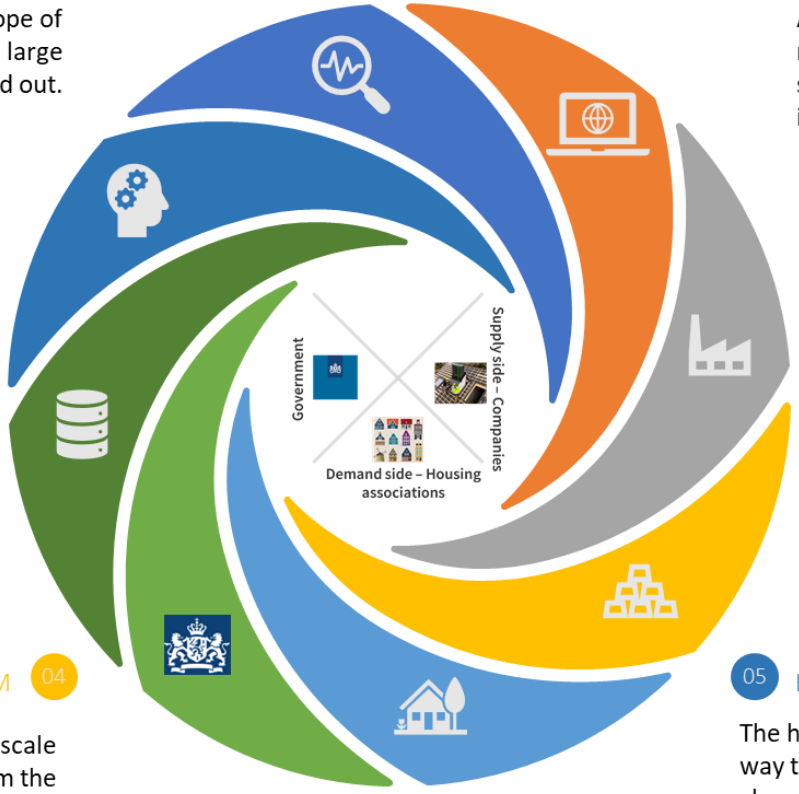
Knowledge sharing and improving the skill sets of the employees in the companies that provide renovation solution by introducing automation and robotics.

03 AVAILABILITY OF DATA

The availability of housing sector data (geometric data, energy calculation etc) must be checked and should be made available.

04 GOVERNMENT SUPPORT SYSTEM

A support system for the large scale renovation of houses is expected from the government by both housing associations and companies with well defined policies.



08 DIGITAL TENDER ON NATIONAL PLATFORM

A digital tendering mechanism which is designed on a national platform should bridge the housing classification system & production of standardized products in a highly industrialized production line.

07 STANDARDIZATION & INDUSTRIALIZATION

Standardisation & industrialization should be the most important evaluation criteria in the tendering mechanism to ensure large scale renovation of houses.

06 CUSTOMIZATION TO MASS-CUSTOMIZATION

The traditional cultural relationship between the clients and solution provider were products are based on the customer satisfaction should be transformed to production of mass-customized products.

05 HOUSING CLASSIFICATION SYSTEM

The housing classification system should be designed in such a way that the housing cluster consists of houses having similar characteristics, renovation solutions & also characteristics important of the companies to standardize the products and processes.

8. Future works

Based on the conclusions drawn from the analysis of this research, it is possible to suggest a number of future works that can be supported in this PDEng program and thus in work package 4.2 of this IEBB project. Also a number of more general future works could be considered, outside the scope of this project.

9.1 Inside IEBB scope

Future work in the scope of this PDEng project is the design of a housing clustering mechanism and tendering mechanism, based on all conclusions made in this report, that can be adopted by housing corporations for the renovation of their large housing stocks. Designing a housing classification system to create large clusters of housing renovations, and a tendering mechanism for a structured, homogeneous, bundled and (multi-year) predictable renovation market would encourage the companies for investing further in industrialization to produce standardised, innovative products in a qualitative and cost effective manner (see also WP4.3 of this IEEB project). The tendering mechanism would also facilitate the companies to accurately list their products and costs for the renovation work.

9.1 Outside IEBB scope

More research work can be carried out on the analysis of housing classification systems and tendering mechanisms in the context of standardizing the renovation solutions and industrialization of the production process. This document made an outset in this analysis, which can be further detailed in forthcoming research. Such work is not targeted inside the scope of this WP, and the reader is referred to the work done in other parts of this project (e.g. WP1 and 2).

9. Acknowledgements

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APPENDIX

1. Following is the questionnaire prepared on Limesurvey for the purpose of the conduction of this project work. Since 100% of the respondents used the Dutch version of the survey, the Dutch version of the questionnaire is provided for reference.

Standaardisatie en industrialisatie van de duurzame renovatie van de bestaande woningvoorraad

Om de Nederlandse klimaatdoelstellingen voor 2050 te halen moeten 7,8 miljoen woningen duurzaam worden gerenoveerd. Het huidige versnipperde proces van woningrenovaties moet worden opgeschaald door de woningen met vergelijkbare kenmerken te bundelen. Zo ontstaat een ideale markt voor het produceren van gestandaardiseerde, kwalitatieve, goedkope en tijdbesparende renovatieoplossingen. Dit resulteert uiteindelijk in grootschalige productie en industrialisatie in de bouwsector.

De resultaten van dit onderzoek worden geanalyseerd en gebruikt om de volgende onderzoeksvragen te beantwoorden.

- Wat is het niveau van standaardisatie en industrialisatie in bedrijven in renovatieprojecten? Hoe kan dit evolueren in de nabije toekomst?
- Welke aanbestedingsmechanismen zijn er momenteel in renovatieprojecten en hoe kunnen aanbestedingsmechanismen worden uitgewerkt en geoptimaliseerd om standaardisatie en industrialisatie te bevorderen?
- Welke woningclassificatiesystemen worden momenteel gebruikt in de renovatiesector en hoe kunnen woningclassificatiesystemen worden uitgewerkt en geoptimaliseerd om standaardisatie en industrialisatie te bevorderen?
- Wat zijn de huidige obstakels bij de introductie en verdere ontwikkeling van industrialisatieprocessen aan de aanbodzijde van de supply chain (toeleveranciers, productie, etc.)?
- Wat zijn de huidige factoren die de industrialisatie aansturen? Hoe kunnen aanbestedingsmechanismen en woningclassificaties kansen bieden om grootschalige renovatie te stimuleren?

Waarom deze enquête:

1. **Korte termijn:** Dit onderzoek maakt deel uit van het project Integrale Energietransitie Bestaande Bouw (IEBB) binnen het BTIC. Door middel van een systematische analyse van deze enquêteresultaten zal een rapport worden opgesteld over de clusteringmethoden van woningen, aanbestedingsmechanismen en de noodzakelijke informatievoorziening aan de aanbodzijde voor standaardisatie en industrialisatie. Behalve de partners in het IEBB-project, zal dit rapport worden gedeeld met de Renovatieversneller en alle bedrijven die aan dit onderzoek hebben meegedaan.

2. **Langetermijn:** Het BTIC heeft verschillende lopende programmalijnen die zich richten op het clusteren van woningen en geïndustrialiseerde renovatie. De uitkomsten van de enquête zullen worden gebruikt om het onderzoek bij het BTIC te sturen. We streven ernaar om inzichten te verkrijgen om oplossingen te identificeren om het proces van geïndustrialiseerde grootschalige renovatie van huizen naar een koolstof neutrale gebouwde omgeving te versnellen in lijn met de meerjarige programmalijnen van BTIC.

We realiseren ons dat deze enquête hier en daar wat de diepte in gaat. We waarderen het ontzettend als u uw waardevolle inzichten met ons wilt delen. Als we te veel de diepte in gaan kunt u altijd vragen overslaan.

Er zijn 30 vragen in deze enquête.

Demografische informatie :

Wat is uw discipline:

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Technische expert
- ◯ Consultant
- ◯ Projectbeheer
- ◯ Procesmanagement
- ◯ Economisch analist / specialist

Geef hier een toelichting op uw antwoord:

Aantal jaren van relevante ervaring:

❗ In dit veld mogen alleen cijfers ingevoerd worden.
Vul uw antwoord hier in:

Functietitel:

Vul uw antwoord hier in:

Hoe groot is uw bedrijf (aantal medewerkers)?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Micro <10
- ◯ Klein > 10 en <50
- ◯ Middelgroot formaat > 50 en <250
- ◯ Groot> 250 en <2.500
- ◯ Zeer groot > 2.500 en <10.000
- ◯ Mega >10.000
- ◯ Ik weet het niet

Geef hier een toelichting op uw antwoord:

Type bedrijf:

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Aannemer
- ◯ Installatie (e.g. W&E installateur)
- ◯ Onderhoudsbedrijf
- ◯ Productontwikkelaar
- ◯ Overig

Geef hier een toelichting op uw antwoord:

Wat is de geografische spreiding van de renovatieprojecten binnen uw bedrijf?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Klein deel van Nederland (bijvoorbeeld binnen één provincie)
- ◯ Regio in Nederland (bijv. meerdere provincies)
- ◯ Heel Nederland
- ◯ Benelux
- ◯ Europa
- ◯ Intercontinentaal
- ◯ Niet van toepassing

Geef hier een toelichting op uw antwoord:

Wie zijn uw belangrijkste klanten in het renovatieproject?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Woningcorporaties
- ◯ Particuliere verhuurders/ investeerders
- ◯ Verenigingen van eigenaars (VVE's)
- ◯ Individuele huiseigenaar
- ◯ Niet van toepassing

Geef hier een toelichting op uw antwoord:

Standaardisatie en industrialisatie van de duurzame renovatie van de bestaande woningvoorraad

Onderzoekers en wetenschappers definiëren geïndustrialiseerde productie als een proces dat tot doel heeft de productie te verbeteren door het traditionele, handmatige productieproces te vervangen door gestandaardiseerde, gemechaniseerde productieprocessen die een consistent betaalbaar product van hoge kwaliteit opleveren.

Industrialisatie omvat het gebruik van geprefabriceerde elementen van groot formaat en de omzetting van de productie in een gemechaniseerd en continu stroomproces van het assembleren en installeren van gebouwen en constructies gemaakt van geprefabriceerde assemblages en onderdelen.

Gelieve kort uit te leggen hoe industrialisatie van bouwtechnieken in uw bedrijf wordt aangepakt?

Als u een consultant / onderzoeker bent, kunt u vanuit uw ervaring en kennis schrijven over de huidige industrialisatieniveaus in de renovatie-sector.

Vul uw antwoord hier in:

Hieronder volgen enkele randvoorwaarden voor industrialisatie die verwacht worden vanuit de aanbodzijde (bedrijven die renovatieoplossingen aanbieden). Rangschik ze van het hoogste belangrijkheidsniveau (5) tot het laagste belangrijkheidsniveau (1).

Kies het toepasselijke antwoord voor elk onderdeel:

	1	2	3	4	5
Automatiserings- en controleprocessen moeten worden gedigitaliseerd	○	○	○	○	○
Robots moeten meer beschikbaar komen (van 3D-printers tot autonome robots)	○	○	○	○	○
Er moet voldoende kennis, expertise en kunde beschikbaar zijn onder medewerkers	○	○	○	○	○
Er moet voldoende kapitaal beschikbaar zijn om te investeren	○	○	○	○	○

Wilt u nog andere randvoorwaarden, knelpunten of belemmeringen toevoegen wat betreft industrialisatie die hierboven niet worden genoemd?

Vul uw antwoord hier in:

Selecteer de industrialisatieniveaus die het meest overeenkomen met het niveau dat in uw bedrijf wordt gevolgd. (Meerkeuze)

Als adviseur / onderzoeker kunt u vanuit uw ervaring en kennis de huidige industrialiseringsniveaus selecteren, gevolgd door de renovatie-industrieën.

Kies het toepasselijke antwoord voor elk onderdeel:

	Traditional renovation techniques (manual labour	Prefabrication techniques (building components are manufactured on a weather-controlled factory site with strict quality controls)	Mechanization (e.g. Use of mobile cranes to lift 2D/3D volumetric units or other advanced machines)	Automation (tasks of employees are taken over by machines)	Robotics (e.g. Demolition robots, robotic total stations, laser scanners, robot drones, bricking robots, welding robots, exoskeletons, forklift robots, and humanoids)	3D printing (Produces objects by building structures from small deposits of materials such as steel, glass, ceramics, polymer, concrete and more in layers)
1 (Momenteel wordt deze techniek in het bedrijf gevolgd)	○	○	○	○	○	○
2 (Wordt geïmplementeerd - laatste fasen)	○	○	○	○	○	○

3 (Planning voor implementatie, in de nabije toekomst, binnen 5 jaar)	○	○	○	○	○	○
4 (Planning om te implementeren, maar in de verre toekomst > 5 jaar)	○	○	○	○	○	○
5 (dit niveau niet volgen)	○	○	○	○	○	○

Ruw geschat % gebruik van de volgende bouwtechniek in de renovatieprojecten van het bedrijf (De som van de ingevoerde waarden moet gelijk zijn aan 100%)

Als adviseur / onderzoeker kunt u vanuit uw ervaring en kennis de huidige industrialiseringsniveaus selecteren, gevolgd door de renovatie-industrieën.

❗ In deze velden alleen cijfers invoeren.
Vul uw antwoord(en) hier in:

Traditionele renovatietechnieken/ handenarbeid

Prefabricagetechnieken

Mechanisatie

Automatisering

Robotica

3d printen

Welke bouwelementen (muren, gevels, vloerpanelen, ramen, deuren, armaturen, sanitair, modulaire keukencomponenten, funderingselementen, dakelementen, andere…) worden vervaardigd met behulp van de volgende constructietechnieken? (bijv. als gevels in de fabriek geprefabriceerd zijn, vermeld dan 'gevels' in het tekstvak 'Prefabricagetechnieken'.)

Bent u adviseur / onderzoeker, dan kunt u op basis van uw ervaring en kennis over de technieken van de renovatie-industrie selecteren en invullen.

❗ Vul alleen een opmerking in als u een antwoord kiest.
Kies alle voor u geldende mogelijkheden en geef een toelichting:

☐ Traditionele renovatietechnieken / handenarbeid

☐ Prefabricagetechnieken

☐ Mechanisatie

☐ Automatisering

☐ Robotica

☐ 3d printen

Anders:

Wat is de grootste omvang van het renovatieproject dat uw bedrijf tot nu toe heeft uitgevoerd?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Een renovatieproject voor één huis
- ◯ Minder dan 10 huizen
- ◯ 10-25 huizen
- ◯ 25 - 50 huizen
- ◯ 50 - 100 huizen
- ◯ 100-250 huizen
- ◯ 250-500 huizen
- ◯ 500-1000 huizen
- ◯ Meer dan 1000 huizen

Geef hier een toelichting op uw antwoord:

Biedt uw bedrijf een renovatieoplossing met een Energieprestatie Garantie?

Kies één van de volgende mogelijkheden:

- ◯ Ja
- ◯ Nee

Bevat de renovatieoplossing van uw bedrijf een gegarandeerd intern comfortniveau voor de gebruikers (e.g. Indoor Air Quality certificates, or similar)?

Kies één van de volgende mogelijkheden:

- ◯ Ja
- ◯ Nee

Aantal dagen dat nodig is om het hele renovatieproces van een enkele woning te voltooien?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ <1 dag
- ◯ 1-5 dagen
- ◯ 5-10 dagen
- ◯ > 10 dagen
- ◯ Weet ik niet

Geef hier een toelichting op uw antwoord:

Hieronder volgen enkele obstakels aan de vraagzijde (huiseigenaars) voor het realiseren van grootschalige renovatie. Rangschik ze van het hoogste belangrijkheidsniveau (5) tot het laagste belangrijkheidsniveau (1).

Bent u adviseur / onderzoeker, dan kunt u op basis van uw ervaring en kennis over de technieken van de renovatie-industrie selecteren en invullen.

Kies het toepasselijke antwoord voor elk onderdeel:

	1	2	3	4	5
Onvoldoende volume (aantal te renoveren woningen)	○	○	○	○	○
Te gevarieerde en onvoorspelbare vraag naar renovatie van huizen	○	○	○	○	○
Grootschalige renovatiewerken genereren te veel overlast voor de bewoners	○	○	○	○	○
Geen uniformiteit in de vraag - geen vergelijkbare/ uniforme woningen	○	○	○	○	○
Geen uniformiteit in renovatiespecificaties	○	○	○	○	○
Onvoldoende kapitaal	○	○	○	○	○
Te weinig ondersteuning door de overheid	○	○	○	○	○

Wilt u bepaalde obstakels toelichten die u heeft ervaren aan de vraagzijde (bv. woningcorporaties, huiseigenaren etc.) die hierboven niet genoemd worden.

Vul uw antwoord hier in:

Zoals in de inleiding is geschetst, zal met het oog op normalisatie en industrialisatie een woningclassificatiesysteem worden ontworpen waarmee woningen worden geclusterd en aanbesteed. In het klimaatakkoord was in het kader van de Renovatieversneller voorzien dat grootschalige aanbesteding van woningrenovatieclusters landelijk georganiseerd zou worden. Met de volgende vragen willen we de eisen afleiden waaraan dit woningclassificatiesysteem moet voldoen om standaardisatie en industrialisatie te bevorderen.

Bent u het eens met de volgende uitspraken.

Kies het toepasselijke antwoord voor elk onderdeel:

	Sterk mee eens	Mee eens	Oneens zijn	Sterk mee oneens
Grootschalige aanbesteding van woningrenovatieclusters standaardisatie en industrialisatie bevordert en het renovatieproces naar 300.000 woningen per jaar helpt versnellen	○	○	○	○

	Sterk mee eens	Mee eens	Oneens zijn	Sterk mee oneens
Grootschalige aanbestedingen van woningrenovatieclusters op een landelijk platform moet worden georganiseerd, voor consistentie in procedures (bijvoorbeeld gestandaardiseerde formaten en eisen voor kwaliteitsborging en prestatiegaranties) waaraan alle partijen moeten voldoen	○	○	○	○
Er een sterke behoefte is dat de woningen binnen een cluster vergelijkbare kenmerken hebben met het oog op standaardisatie en industrialisatie	○	○	○	○
Er een sterke behoefte is aan vergelijkbare renovatieoplossingen	○	○	○	○

Stel je voor dat je hebt geïnvesteerd in de industrialisatie van je productieprocessen (prefabricage, mobiele kranen, robots, automatisering, 3d-printing enz.), waarbij je de komende 5 jaar een sterke stijging van de renovatie van woningen voorziet, en de grootschalige aanbesteding van renovatieclusters. Wat is in deze situatie het gewenste/ optimale aantal woningen dat u in een renovatiecluster wilt hebben, ervan uitgaande dat u 3-4-5 jaar nodig heeft om de renovatiewerken uit te voeren? (Dit antwoord zou helpen bij het ontwerpen van de grootte van het cluster van huizen dat per jaar wordt gerenoveerd)

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ 25 - 50 huizen
- ◯ 50 - 100 huizen
- ◯ 100-250 huizen
- ◯ 250-500 huizen
- ◯ 500-1000 huizen
- ◯ 1000-5000 huizen
- ◯ 5000-10000 huizen
- ◯ Minimaal 10.000 huizen

Geef hier een toelichting op uw antwoord:

In de Renovatieversneller werd voorzien dat bedrijven na aanbesteding een bepaalde hoeveelheid tijd zouden krijgen om de renovatiewerken uit te voeren aan een cluster, met als doel een continue productie mogelijk te maken. Hoeveel jaar moeten bedrijven de tijd krijgen om het werk uit te voeren?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ <2 jaar
- ◯ 2-3 jaar
- ◯ 4-5 jaar
- ◯ 5-7 jaar
- ◯ > 7 jaar

Geef hier een toelichting op uw antwoord:

In de Renovatieversneller is het de bedoeling dat woningen geclusterd worden om 'soortgelijk' te zijn, om zo een vraag te creëren die kan worden gestandaardiseerd. Het is momenteel echter onduidelijk welke woningen kunnen worden beschouwd als behorend tot hetzelfde cluster (voor normalisatie en industrialisatie) en welke niet. Stel je twee identieke woningen voor, geef voor onderstaande kenmerken aan of deze variaties in hetzelfde cluster moeten zitten of niet. (Absoluut moeten = ze zouden in hetzelfde cluster moeten zitten, wat betekent dat de variaties kunnen worden meegenomen in een gestandaardiseerd, geïndustrialiseerd renovatieproces).

1- Zou zeker

2- waarschijnlijk zou moeten

3- Geen reacties

4- waarschijnlijk niet

5- zou zeker niet moeten

Kies het toepasselijke antwoord voor elk onderdeel:

	1	2	3	4	5
Verschillende indeling van de ramen in de gevel	○	○	○	○	○
Verschillende dakvorm	○	○	○	○	○
Verschillende toevoegingen (dakkapel, uitbouw begane grond, etc.)	○	○	○	○	○
Een tussenwoning en een hoekwoning (beide rijtjeshuizen)	○	○	○	○	○
Een rijwoning en een vrijstaande woning (verschil in typologie)	○	○	○	○	○
Een rijtjeshuis en een appartement (verschil in typologie)	○	○	○	○	○

	1	2	3	4	5
Verschillende soorten vloerconstructie	○	○	○	○	○
Verschillende soorten dakconstructie	○	○	○	○	○
Ander type wandconstructie	○	○	○	○	○
Verschillende spouwdiepte	○	○	○	○	○
Ander bestaand isolatieniveau	○	○	○	○	○
Verschillende gewenste renovatieoplossing: verschillende isolatieniveaus	○	○	○	○	○
Andere gewenste renovatieoplossing: ander HVAC-systeem	○	○	○	○	○
Verschillende gewenste renovatieoplossing: verschillende afwerkingen	○	○	○	○	○
Andere buurt/ stad	○	○	○	○	○
Andere regio/ provincie	○	○	○	○	○
Ander eigendom (woningcorporaties/ VVE/ particuliere woningeigenaren)	○	○	○	○	○

Massaproductie is de productie van grote hoeveelheden gestandaardiseerde producten, vaak met behulp van assemblagelijnen of automatiseringstechnologie. Welke van de volgende bouwelementen denkt u dat uw bedrijf in de toekomst in massa zal produceren voor grootschalige renovatieprojecten?

❗ Vul alleen een opmerking in als u een antwoord kiest.
Kies alle voor u geldende mogelijkheden en geef een toelichting:

- [ ] Muren
- [ ] Gevels
- [ ] Vloerpanelen
- [ ] Ramen
- [ ] Deuren
- [ ] Uitrusting
- [ ] Badkameraccessoires
- [ ] Modulaire keukencomponenten
- [ ] Dakelementen
- [ ] Funderingselementen
- [ ] Anderen

In de Renovatieversneller is voorzien om woningen aan te besteden op een landelijk platform, waar aannemers en consortia kunnen bieden op uitvoering van de grootschalige renovatieclusters.

Welk niveau van informatie van de woningen heb je nodig om comfortable deel te kunnen nemen aan dergelijke aanbesteding van een grootschalige renovatiecluster en om een offerte te kunnen opmaken (ervan uitgaande dat de renovatie-eisen duidelijk zijn gespecificeerd)? Rangschik elke informatiebron die hieronder wordt gegeven van hoogste belang (5) naar laagste belang (1).

Kies het toepasselijke antwoord voor elk onderdeel:

	1	2	3	4	5
BAG-data (typologie + bouwjaar)	○	○	○	○	○
Basisbeschrijving van de belangrijkste kenmerken (glasoppervlak, vloeroppervlak, dakvorm, wand-/ vloer-/ dakconstructietype, etc.)	○	○	○	○	○
Bouwtekeningen	○	○	○	○	○
3D-scan van de buitenkant	○	○	○	○	○
3D-scan van het interieur	○	○	○	○	○
Vereenvoudigde documentatie van energie labels	○	○	○	○	○
Uitgebreide documentatie over energie labels	○	○	○	○	○

Wilt u nog andere informatie (die hierboven niet vermeld staat) van de woningen vermelden die u nodig heeft om comfortable mee te kunnen doen aan de aanbesteding van een grootschalige renovatiecluster, en een offerte te kunnen opmaken (ervan uitgaande dat de renovatie-eisen zijn duidelijk gespecificeerd)?

Vul uw antwoord hier in:

Welk belang moet worden gehecht aan de volgende criteria in het evaluatieproces van aanbestedingen?

Kies het toepasselijke antwoord voor elk onderdeel:

	Tijd per woning	Kwaliteit van renovatie	Communicatie met bewoners	Milieu-impact van de bouwwerkzaamheden	Industrialisatie	Innovatie van proces en techniek	Kosten
Weinig belang	○	○	○	○	○	○	○
Gemiddeld belang	○	○	○	○	○	○	○
Groot belang	○	○	○	○	○	○	○

Wat moet het aantal contractanten zijn dat voor het geselecteerde aanbestedingsproces moet worden uitgenodigd?

❗ Kies één van de volgende antwoorden
Kies één van de volgende mogelijkheden:

- ◯ Slechts 2-3
- ◯ 5-10
- ◯ > 10
- ◯ Open voor iedereen

Geef hier een toelichting op uw antwoord:

Zijn er regelgevende of bureaucratische belemmeringen (bijv. In verband met vergunningen) die moeten worden opgelost bij grootschalige aanbestedingen?

Vul uw antwoord hier in:

Hartelijk dank voor uw tijd. Aarzel niet om verdere opmerkingen of suggesties te geven.

Vul uw antwoord hier in:

U heeft de enquête met succes ingevuld !!! Hartelijk bedankt !!!

Mocht je meer willen weten over dit project en / of de resultaten van dit onderzoek, neem dan contact met mij op via onderstaande gegevens.

Anusree Mohan / a.mohan@tue.nl

Verzend uw enquête.
Bedankt voor uw deelname aan deze enquête.