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A synthesis of the top-down policies and bottom-up community designs in Dutch co-housing that influence energy efficiency

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Contents

List of Figures

List of Abbreviations

OECD	Organization for Economic Co-operation and Development
EPBD	Energy Performance of Building Directive
EU	European Union
EPC	Energy efficiency coefficient
NZEB	Nearly Zero-Energy Buildings
EED	Energy Efficiency Directive
ISDE	Sustainable Energy Investment Subsidy
NEF	National Energy Savings Fund
SEEH	Homeowners Energy Saving Subsidy
LTRS	Long-Term Renovation Strategy
BCW	Behaviour Change Wheel
SDG	Sustainable Development Goals
LED	Light-emitting diode
VAT	Value Added Tax

ABSTRACT.

The run-of-the-mill housing provision of single-family units is characterized by high energy demands and therefore societies are moving towards energy efficient urban design to tackle and address the underlying sustainability issues like greenhouse gas emissions, climate change and the transition towards renewables. To realize energy efficiency in the residential sector, co-living initiatives are adopted as a promising solution where individuals live as a community in shared apartments or households consisting of common facilities like community gardens, kitchens, laundry spaces, green spaces and living spaces/areas. Sharing aggregate building space and combined utility management presents great opportunities to maximize energy efficiency. The concept in the Netherlands is a grass-root concept mainly executed by housing cooperatives in collaboration with the municipalities to provide communal projects for low and middle income earners and the elderly. The co-housing initiative falls in line with the Dutch sustainable goals and the European green deal with the aim of having sustainable cities and greener lifestyles, further it contributes solutions to solve the housing deficit. The Energy Performance of Building Directive and the Energy Efficiency Directive are the European Union frameworks that establishes and promotes energy efficiency policies in both new and existing building stock. This research conducted a comprehensive analysis of the two policy frameworks with a focus on the key specific instruments used. In addition to the policies, co-housing residents are regarded as the key drivers in realizing energy efficiency. Therefore five co-housing case studies were analyzed with an objective of assessing the technical features and interactions between tenants-tenants and tenants-technological artefacts that help realize energy efficiency. The research identified several structural and informational instruments used to encourage energy efficiency namely: Sustainable Energy Investment Subsidy (ISDE), National Energy Savings Fund (NEF), Homeowners Energy Saving Subsidy (SEEH), Energy Performance Incentive Scheme for the Rental Sector (STEP), Energy Savings Fund for the Rental Sector (FEH) and the Sustainable Heat and Cold Built Environment Programme

Key words: Co-housing, Energy efficiency, Socio-technical systems.

1. Introduction

1.1 Background

The global world population is increasing gradually and is expected to rise from 7.9 billion now to a staggering 9.7 billion come 2050, with over 750 million people living in Europe. The increase in population has resulted in rapid urbanization and urban sprawl, further, exerting more pressure in the housing market and more energy demand. The Dutch housing market is currently experiencing a boom after a crisis recession period between 2008 and 2014. However, with the current boom, the housing demand is still high coupled with insufficient supply, chronic price accelerations and high energy demands (Guide, 2021). The low and middle-income households in the Netherlands are facing the brunt of the housing market due to a myriad of factors like population growth, privatization of the housing sector leading to high prices and a blend of registration directives, this group also falls in between the social housing and market sector. Therefore there is limited supply of housing to serve the needs of this group (Roggeveenstraat, 2020).

The aggregate energy consumption in buildings is gradually increasing and this phenomenon will continue in the future. U.S Department of Energy (2019) indicates that by 2050, OECD countries will have a 15% increase in energy consumption. The Dutch government in a bid to achieve a carbon-free economy has set out directives to increase renewables to 32% by 2030 and through the National Climate Agreement to reduce greenhouse gas emissions by 49% by 2030. These aforementioned transitions require maximum effort in each energy-dependent sector, of interest is the built environment, the sector is special as it enables open collaboration and participation (Mateos, 2020). European Environment Agency (2020) claims that over the years the EU has recorded significant reduction in GHG emissions from the building stock, with a noteworthy decrease since 2005 as shown in figure 1. This is due to the implementation of new policy directives for both existing and new buildings, for the existing buildings an extensive renovation strategy is in place to ensure that existing buildings are fitted with new efficient heating and insulation systems.

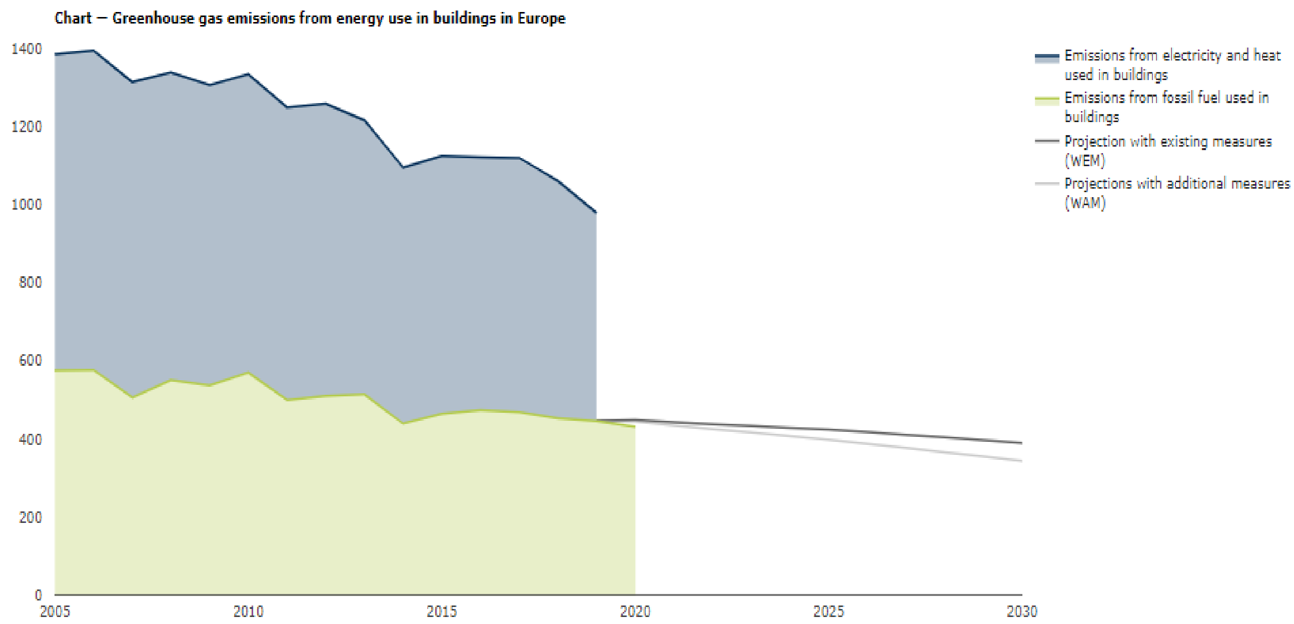

Figure 1 Greenhouse gas emissions in million tonnes from energy use in buildings in Europe in (European Environment Agency, 2020)

1.2 Problem Statement

The built environment with the contingent residential sector is a significant component in the global energy consumption and further contributing towards climate change. Buildings account for 40% of global energy consumption and a further 33% of greenhouse gas emissions (Energy Performance of Buildings Directive, 2018). Energy consumption is the highest during the use phase of the buildings as energy is used run the daily operations of a building and this is where the environmental impacts are felt most.

However, the technological artefacts of a building greatly influence the operational demand of energy and therefore from the building's foundation all the way to the roofing requires proper choice of construction material with less carbon footprint in order to achieve energy efficient buildings (Heeren et al., 2015). Both behavioral and technical factors are crucial in realizing energy efficiency. Tenants' behaviour during the building's life cycle should be geared towards the least energy use as possible, due to these reasons the co-housing concept is a potential solution to efficient energy use in buildings. New innovations like straw construction are realized through these projects as like-minded individuals come together to develop a sustainable project, not forgetting that the same initiators become tenants and through their sustainability mindset, aggregate sharing of space reduces energy demand as a behavioral factor.

The impact of the built environment has prompted the Netherlands to set down a couple of policy directives to be followed to realize energy efficiency in buildings. These policies are hinged on EU's European Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED). The EU has set environmental and energy targets to realize 39% energy efficiency and 36% reduction in energy consumption by 2030. This focus not only ensures energy efficient buildings but also seeks to improve quality of life of the citizens, improved indoor enjoyment and comfort (Energy Performance of Buildings Directive, 2018).

Within this context co-housing initiatives offer a number of energy benefits, Tummers (2016) states that "co-housing is raising interest as innovator of housing and sustainable environmental technology"(p.3). Through co-housing initiatives, residents not only become consumers but also act as co-producers of housing. Aside from pooling resources, residents of the co-housing initiatives are more receptive to renewable technologies with the application of ecological artefacts (Seyfang, 2008). A number of scholars have done research on the co- housing however most have focused on the social advantages for example Kat (2019) "*Co-housing in the Netherlands 'living with friends as neighbors and neighbors as friends."* focuses on co-housing as a solution to the ageing society as they can live together with other people avaoiding loneliness.

Most of the literature also looks into the different definitions of co-housing, its history throught Europe, the different forms of co-housing that exist. Tummers (2017) *"Learning from co-housing initiatives: Between passivhaus engineers and active inhabitants."* explores the link between co-housing initiatives and voluntary energy labelling. However research about how the policies and socio-technical systems that exist between tenants here in the Netherlands is one that has not been done yet therefore this research seeks to find these crucial elements of co-housing and subsequently contribute to the pool of knowledge.

1.3 Research Objectives

The main objective for this research is to understand how Dutch policies and social behaviour stimulate energy efficiency with a specific focus in the context of co-housing projects. As discussed previously co-housing initiatives are important avenues to realizing sustainable urban development, touching upon the multiple SDGs including the energy transition towards renewables (Scheller & Thörn, 2018). It is therefore important to study how co-housing relates to energy efficiency and how related policies relate to and interact with this type of innovation.

To sufficiently achieve the main goal of the research, four specific objectives are developed to guide and give more detail of how the main objective will be approached. The specific objectives include:

- To understand which specific policies have been put in place with an objective of realizing energy efficiency in co-housing projects.
- Furthermore in connection to the previous objective to explore the specific instruments put in place to facilitate the policies
- To get an insight on the design features of co-housing projects and how co-housing tenants interact with these features to help to realize energy efficiency.
- Based on the assessment of policy and given residents' behavior how can the relevant government authorities motivate and encourage communities to realize energy-efficient living in co-housing projects.

1.4 Research Questions

The aforementioned objectives are accommodated by answering the following overarching research question: *How do Dutch green building policies stimulate energy efficiency in co-housing projects?* This however can be broken down into the following sub-questions:

1. Which Dutch green building policies exist and how do they stimulate energy efficiency in co-housing projects?
2. Which policy instruments does the government use to facilitate energy efficiency?
3. Which building design features are found in co-housing initiatives and how do tenants interact with these features to realize efficient energy use?
4. How can the relevant government authorities stimulate behaviour change towards the adoption of energy-efficient co-housing projects?

1.5 Research Framework

This research applies two theories to frame and explore its research questions: behaviour change policy wheel and socio-technical systems theory. The behaviour change policy wheel will help explore process of policy decision making towards facilitation of efficient practices in co-housing projects. At the same time the socio-technical systems theory will focus on understanding the diffusion of new technologies promoted in the context of co-housing projects, in a society with heterogeneous social needs.

1.6 Contribution of the thesis

This research will contribute to the scientific fountain of knowledge in several ways, first through the application of the behaviour change policy wheel to analyze energy efficiency policy directives that are in place. This thesis will also contribute to how energy efficiency is realized through socio-technical systems: how social cohesion and the interaction with technology motivates people to start living sustainable lifestyles, in terms of societal contribution. The thesis aims to increase awareness on the energy saving capabilities of co-housing projects and the consequent development of the initiatives.

1.7 Thesis Outline

This thesis contains six chapters, the first chapter is the **introduction**, this chapter introduces the background idea of the topic, the problem statement is defined in this chapter followed by the research objectives, research questions and the research framework, this first chapter forms the frame to the thesis. The second chapter is **literature review**, under this chapter the co-housing concept is first described followed by the link between co-housing and energy efficiency. The third chapter consists of the **theoretical framework** where two theories are explored to support answering of the research questions, the fourth chapter looks into the **research strategy** employed to answer the research questions, the fifth chapter focuses on the different Dutch energy efficiency directives the sixth chapter is dedicated to the five different **case studies of co-housing projects** in the Netherlands, the seventh chapter focuses on the **summary findings** and finally the eighth chapter looks into **conclusions and recommendations.**

2. Literature Review

Scholars have explored co-housing and energy efficiency from different perspectives. Tummers (2017) explores the architectural and engineering design aspects of co-housing projects and how they manifest to realize sustainable living. Scheller & Thörn (2018) examine co-housing as an avenue to the realization of sustainable cities. This research aims to fill several research gaps by reviewing literature on the co-housing concept and its link to energy efficiency in the context of policy and social interactions of tenants, previous studies have focused on the concept of social cohesion but not the influence it has on energy efficiency.

2.1 The Co-housing Concept

The co-housing initiatives developed worldwide in the 1960s as a way of achieving healthier environments and greener sustainable lifestyles, these initiatives seek to realize economic, social and ecological sustainability within the society. Co-housing in the Netherlands developed later in the 1970s as a set of private dwellings set in clusters with the residents sharing facilities such as the gardens and kitchen spaces. These spaces were designed to enforce a sense of community and togetherness (*The Spread of Co-Living in the Netherlands*, 2016). These initiatives came about as a response to sustainability queries and shortage of housing, they are developed conjointly and self-managed by the residents themselves, not only do the residents share spaces but also aid each other in their day-to-day activities and interact with one another in a communal way (Kat, 2019).

Across Europe, communities come together and take the initiative to jointly construct and maintain their housing(e.V & Wohnbund, 2015). Climate change, shift to renewable sources, and promoting the shift to a circular economy are the three core concerns of sustainability that co-housing initiatives address (Tummers, 2015).*Centraal Wonen* as known in Dutch gathered more momentum in the 1980s creating a global system of shared space living coupled with diverse forms of management. The tenants usually come together and form a cooperative to build and manage projects, however most of these cooperatives have eventually grown over the years to become big companies (Tummers, 2017).

Residents in co-housing generally agree to a new way of life in matters like consumption habits, and mobility (introduction of car-pooling). The co-housing initiative is merely one of the strategies to bring about these changes. Co-housing projects enable inhabitants to transition from passive consumers to active co-producers of housing as well as everyday services like laundry, daycare and catering along with various management styles (Jarvis, 2011). Residents in these projects encourage the use of recycled water, garbage, and renewable energy sources within the project by pooling resources. Some initiatives demonstrate how direct management by residents can result in long-lasting solutions and financial gain that is ploughed back into the cooperative. These experiments are a perfect example of grassroots initiatives (Seyfang, 2008), and such initiatives are gaining popularity as pioneers in sustainable urban living and housing innovations (Tummers, 2015).

2.2 Co-housing and Energy efficiency

The standard fossil fuel based energy systems is characterized by a centralized distribution system where the supply of energy is from big energy companies usually with the government controlling the delivery. These systems are marred with a high rate of energy wastage due to the numerous extensive distribution systems and financial losses due to the transportation costs within the networks. The new energy transition where societies are moving towards renewables offers a more decentralized system with decentralized sources of energy, due to this nature, smart grids are adopted to absorb the fluctuations that arise from the demand and supply of energy at the same time. The EU has set aside funds to steer research into new hardware and software that aid in regulating these new smart grids and the consumers are able to access energy efficient technologies like self-reading meters and smart homes (Tummers, 2017).

These programs initially were only focusing on the technical aspects leaving out the end-user component, although the latter is vital in the effectiveness of the technology. Co-housing initiatives have been countering environmental concerns by integrating the end-user fully into the technology, not only in the physical real estate but also in a social dimension where residents' activities like consumption of food, access of goods and services, mobility and all the daily routines that impact the environment are steered towards sustainable habits and manners. Emphasis is mainly put into the reduction of the energy bill though (Baborska et al, 2014).

Videras et al. (2012) argues that tenants who live within a “green” neighborhood are more likely to participate in jointly-based sustainable activities and in return seek for other individuals with the same ideology. As a result, sustainable societies/communities jointly participate in energy intense activities which in return reduces the amount of energy used compared to contemporary housing units. Communities involved in sustainable practices are profoundly linked to pro-environmental characteristics which stimulates the day-to-day social practice of tenants in a co-housing project (Flint, 2013).

The structural design of co-housing initiatives is characterized with functional rooms which play a big role in energy efficiency, for instance when tenants meet and socialize in these rooms and it becomes a normal habit that these spaces will be used more frequently and private homes will require less heating time (Tummers, 2016). The sharing of common rooms is not the only activity that stimulates energy efficiency, Kido (2011) examines the advantages of sharing other resources like laundry facilities, play areas and TV rooms. Some projects have common rooms that serve more than one purposes, for instance, one project features a small, soundproofed area for music rehearsal that is used a few times per week, the same room is used as a yoga studio, these two activities interchange, therefore, there is no need for heating, and there is ventilation in between uses.

Stevenson et al. (2013) alludes that residents may be drawn to the common-house fire instead of all individual residents heating their single unit dwellings, these common houses also serve as TV rooms where a projector is mounted to offer a home-cinema concept. With this initiative multiple energy use of televisions in the single dwelling units of 10 to 40 parallel families can be replaced with a single projector. Most co-housing projects also have transitional spaces like the installation of glazed corridors, bigger stairways, covered courtyards and wider hallways, this standout design element of self-managed housing developments serve as buffer zones between heated interior residences and outside temperatures, the intermediate spaces are crucial for informal interactions. This mix of buffers is crucial in energy conservation and provides space to improve informal interactions between inhabitants more extensively (Williams, 2005).

Joint and collective learning of hardware operations and the influence of modified behavior are prerequisites for the hardware to operate at its best, which influences actual performance. Chatterton (2013) for instance, explores a co-housing project named Lilac, situated in Leeds which encourages members to use the laundry facility during the day so that the washing machines can run on self-generated solar power on site. This lowers the cost of energy without necessarily lowering demand in kWh. The joint learning, need to conserve energy and the desire to use renewable energy sources were shared throughout the project with varying degrees of comprehension of the energy-related equipment. (Baborska et al, 2014).

Housing projects that are jointly constructed and the grouping of units create opportunities outside of individual residences. For instance, Tillie et al. (2014) mentions the potential for reusing energy flows at an intermediate scale. The use of alternate sources, such as geothermal or cogeneration, which are typically too expensive for single residences is also made possible by clustered building. According to data from demonstration projects, additional material and piping cost savings for group high-tech energy utilities may be made. Single dwelling units possess extensive internal distribution systems resulting in transport losses for heat or hot substances and ineffective ventilated air heat recovery systems (Stofberg, 2000). Co-housing initiatives are pioneers in reducing the amount of energy used for heating purposes compared to private dwellings.

An active involvement of residents both current and future on environmental protection are typical of co-housing initiatives. The subsequent cohousing generations express the energy standard they are aiming towards in various ways, while the residents association frequently works as a formal partnership, thus the decisions on energy-related design are also influenced by their capacity to bargain with institutional partners. The Dutch cases demonstrate how institutional partners like housing organizations and construction companies might not be able or ready to innovate. Because of the split-incentive, they are less likely to pre-invest in order to lower energy expenses during the project's lifespan. Tummers (2016) gives an example of a co-housing project situated in Zwolle, which worked with an innovative housing partner. The partnership received funding to test out brand-new solar panels. Through monitoring, the homeowners identified an issue with the technology, and they worked together to find a solution.

Palojärvi et al. (2013) argues that since the inception of co-housing initiatives the main concept of these projects has been to reduce the carbon footprint and offer nearly zero energy dwellings for the current and future generations. These ambitions are not only focused on reducing the demand for energy but also promoting the shift towards renewables, they not only focus on direct energy use reduction but also ensuring that the construction materials and water are produced in an eco-friendly manner with the least energy possible often through recycling (Locatelli et al, 2011). Co-housing initiatives also focus on reducing energy being used for mobility, this is made possible through car sharing initiatives and most of them are located in close proximity to essential services.

Lastly, the initiators of co-housing initiatives offer leadership throughout the lifespan of the development, these individuals are tenants but also provide maintenance, administrative and management services, through this arrangement tenants have the opportunity to influence how they consume energy, with the social cohesion created, behaviour change towards energy efficient practices is easy to realize, the collective decision making and idea sharing stimulates the adoption of new technologies and creates a platform for energy efficient innovations (Tummers, 2016). Due to these ambitious environmental practices of the co-housing initiatives, many projects are testing grounds for energy transition and energy efficiency in the housing sector, under the new regime consumers of energy are transitioning to be "prosumers" not only by generating their own energy but also collaborate with the suppliers to acquire green energy and new smart technologies (Tummers, 2017).

3. Theoretical Framework

3.1 Socio-technical system theory

The second set of objectives aimed at understanding the energy efficient technical features and how tenants get to interact with the technological artefacts. The first objective has already been discussed in the results section. Understanding this relationship will be aided by exploring the existing socio-technical systems, a theoretical framework focusing on the socio-technical systems theory. This will help straighten out the ever changing complex problems regarding energy efficiency. A socio-technical system integrates technology and social aspects of society. An analysis of a socio-technical system is crucial in development of remedies to the problems resulting from climate change and managing the impact of anthropogenic hazards (Dwyer, n.d.).

The sociotechnical approach appreciates that new technologies once introduced into the society cause social changes. Fischer (1992) alludes that technological developments penetrates a society from outside and in return influences the various elements of a society, which in turn impact each other, the socio-technical approach appreciates feedback loops in the different phases of technology development and diffusion. The socio-technical theory consists of two main components relevant to energy efficiency, these are role of feedback loop and the notion of a system goal (Dwyer, n.d.). The notion of the system goal is relevant in ensuring environmental sustainability, this is relevant because the EU and the Netherlands have set out energy efficiency goals which are in line with sustainable goals and the European green deal.

(Gallagher et al, 2012) focuses on innovation as a joint activity integrating many different stakeholders and information feedbacks strongly controlled by the different institutions in place. The second component of feedback loops is relevant in terms of relaying information back to an agent, who in this case will be the relevant authorities, the relevant authorities provide the consumers with their energy consumption reports and advises them on methods to reduce energy demand by adopting efficient technologies

A socio-technical perspective broadens the focus over and above energy efficient technologies to include culture, policy environment, social norms, infrastructure, markets and practices. Therefore, to successfully launch an innovation one needs to embed the product into the different heterogeneous environments including user environment, policy environment and the business environment, this is relevant in order to meet the various end-user needs including psychological needs and technical needs.

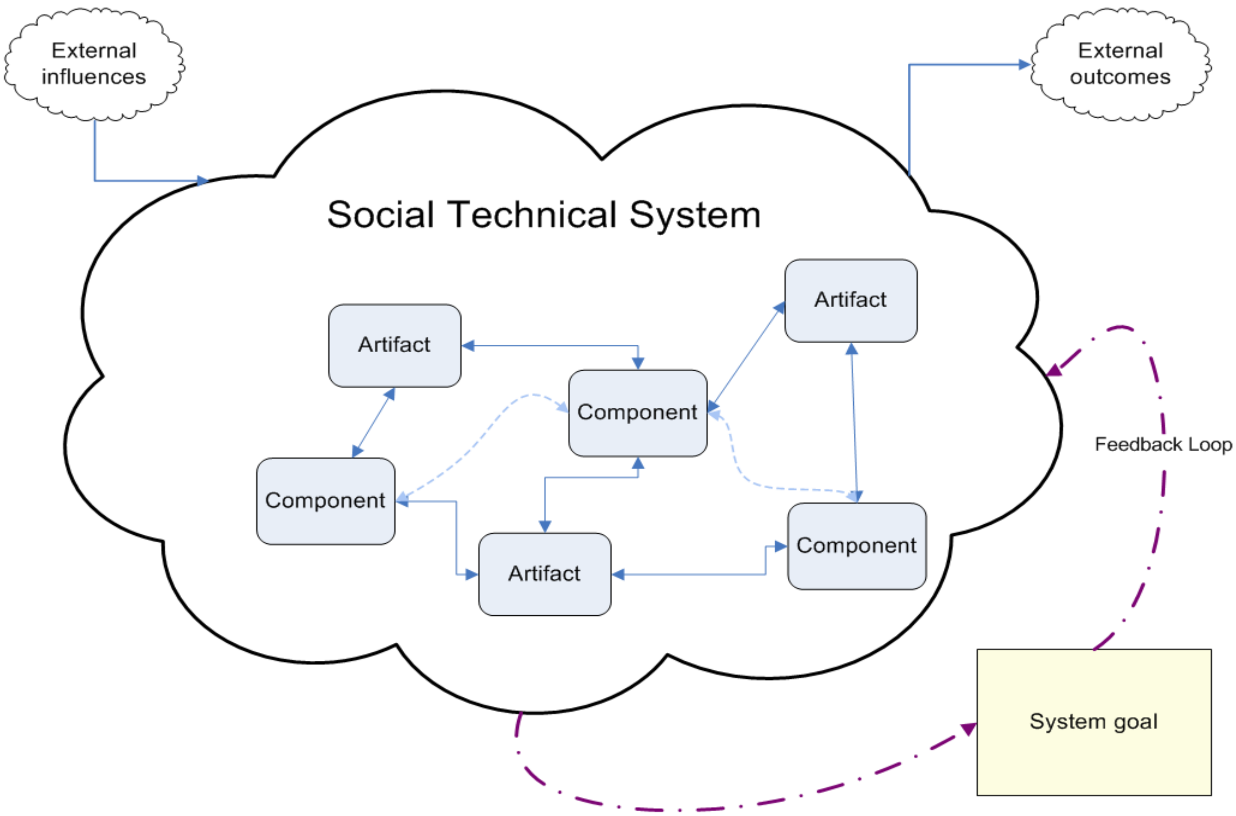

Figure 2 The structure of a socio-technical system, based on (Hughes 1989).

The socio-technical system theory is validated by the five case studies looking into the relationships between the tenants and technologies with an aim of achieving energy efficiency, the five case studies look into how the human-ware in co-housing initiatives interact with the software and hardware all with a similar system goal of achieving efficient energy use, the results from the case study will be able to link with the structure as illustrated on figure 2 above with the artifact representing the technology, the component representing the humans and how these items interact to achieve the common system goal, the feedback loops is through the collective meetings that are held to share ideas and solve problems.

3.2 The Behaviour Change Wheel

To analyze and explore the effectiveness of the energy efficiency policies which is the first objective a theoretical framework is explored in the research as a guide to analyze and understanding the policy decision-making process. “It is like a pair of glasses that will be used to observe the research object.”(Verschuren et al., 2010). Improvement and implementation of policies in the energy efficiency domain requires a focus on the end-user of a project behaviour, a plethora of frameworks regarding change of behaviour guides policy makers to settle down on a policy (Wilson & Marselle, 2016).

The research will analyze the energy efficiency policies/interventions aimed to at swaying end-user energy efficiency behaviour of co-housing dwellers, the research will assess whether they are effective with the guidance of the Behaviour Change Wheel (BCW). The BCW has been applied before by researchers in different domains. Jackson et al. (2014) adopted the BCW to characterize and assess public health policies specifically looking at adherence to prescribed medication. Michie et al. (2011) adopted the BCW to distinguish policies towards tobacco use and obesity. The European Commission through the EU Intelligent Energy–Europe (IEE) Programme developed a project to review behavioral theories as a guide to develop energy efficient policies(Gynther et al., 2012).

This Behaviour Change Wheel (BCW) framework as shown on figure 3 explores nineteen different behaviour frameworks, where the common frameworks are amalgamated to a model of a particular behaviour. The BCW originally roots from psychology and focuses on opportunity, capability and motivation when trying to elicit behaviour change, it also accommodates the social and physical characteristics of an environment (Wilson & Marselle, 2016). The BCW visual representation consists of three concentric circles, the inner hub contains three behaviour sources/factors that influences its existence and what prevents change, the middle circle comprises of the intervention functions and finally the outer rim contains the different policy categories (Gynther et al., 2012). The components do not have a linear relationship as they all relate to each of the other components in the circle, “components within the behaviour system interact with each other as do the functions within the intervention layer and the categories within the policy layer.” (Michie et al. 2014).

The energy efficiency domain highly depends on social and public information awareness, society campaigns towards consumer behaviour leads to substantial energy saving practices with various studies showing a potential of upto 20% improvement. “Improvement of energy efficiency and related market transformation require informed consumers and awareness among all segments of society as well as tailored information, education and training for selected stakeholders”(Gynther et al., 2012)

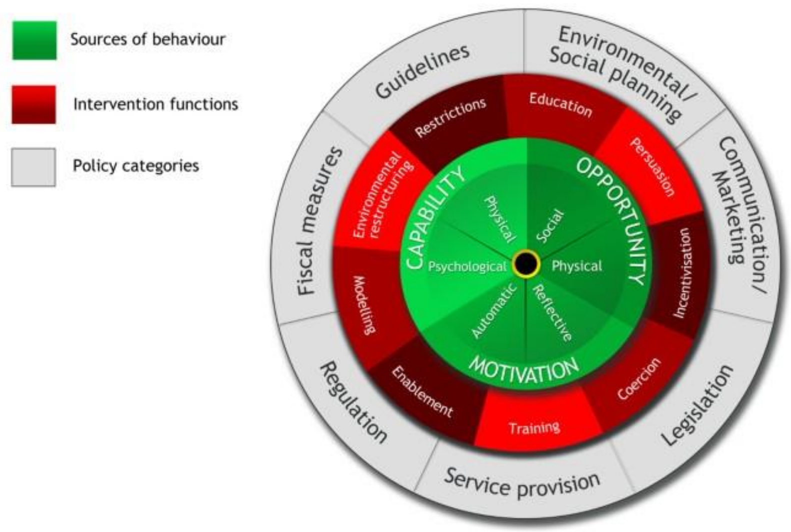

Figure 3 The Behaviour Change Wheel by Michie et al.

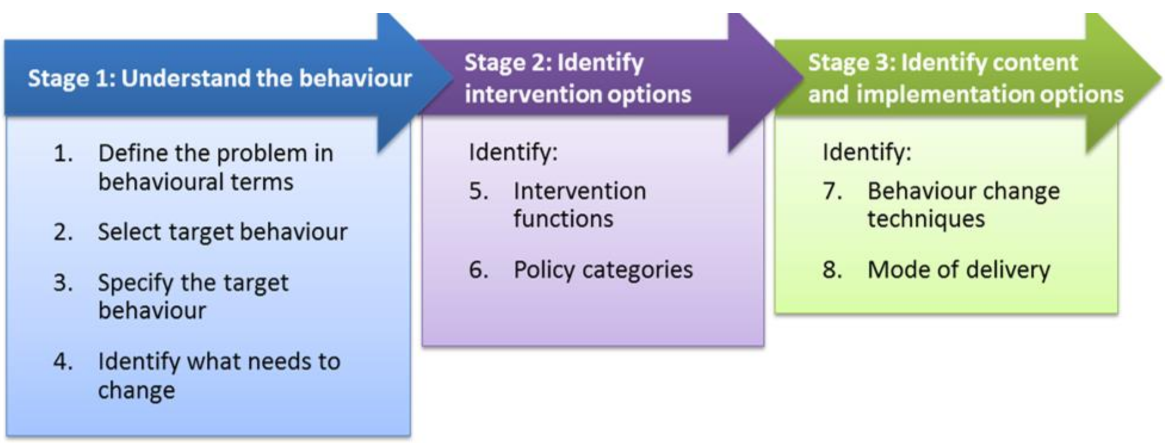

Figure 4 The Behaviour Change Wheel intervention stages by Michie et al.

4. Research Strategy

The research strategy in this research is a combination of desk research and case study, with the former aiming to identify information on policies whereas the latter aims to gain information on the socio-technical systems. It is noted that a case study research is a research strategy where one strives to get a comprehensive understanding of one or more objects or processes that are constrained by time and location. This research strategy is characterized by: small number of research units, intensive data generation and a selective strategic sample (Verschuren et al., 2010). The methodologies applied to acquire the data are as stated below.

4.1 Research Unit

The research units in this project are the energy efficiency policies specifically the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED). The socio-technical systems that influence energy efficiency is the other research unit, where the tenants and initiators of co-housing projects are the social research units to assess behavioral patterns of the tenants and developer practices which stimulate energy efficiency.

4.2 Data Sources and Collection Methods

Originally this study aimed to incorporate both primary and secondary sources of data. The primary data was to be collected from interviews: however, most interviewees failed to schedule the interviews on time while others did not reply back. Therefore the sources of data in this research came from secondary data that is from the desk research. The interviews were to be used to acquire information from the initiators and co-housing tenants with an aim to understand the unique features of the co-housing projects and to understand the relationship between the hardware, software and human ware. In light of low or no response rate secondary sources were used to fill these information needs, sourced from policy documents, reports other available literature in regard to the policies and online sources of co-housing project information.

Table 1 below shows the final methodology used to answer all the research questions

Research Sub-question	Data to be collected	Source of data	Accessing Data
Which Dutch green building policies exist and how do they stimulate	Extensive literature review from grey	Publicly available policy documents,	Desktop research in scientific

energy efficiency in co-housing projects?	literature and scientific articles	government articles and reports.	websites i.e. Web of Science
Which policy instruments does the government use to effect energy efficiency?	Literature review findings Theoretical framework on the BCW	Policy review documents Articles, reports	Desktop research from official scientific research websites
Which building design features are found in co-housing initiatives and how do tenants interact with these features to realize efficient energy use?	What are the different technologies installed to ensure energy efficiency and how do the tenants co-exist with these technologies to ensure energy efficiency.	Secondary data: Publicly available reports, articles and project portfolios	Desktop research from project websites

4.3 Data Analysis

The first step of data analysis will be reviewing the data from policy documents and previous work on energy efficiency policies to understand the numerous policies put in place to stimulate energy efficiency. Analysis of this data will be through content analysis where the research will delve into the policy instruments adopted and comparing them with successful interventions to gauge on its effectiveness consequently. With the aid of the BCW the research will assess the different frameworks adopted to settle on policy interventions by comparing it with the framework interventions.

The second step is assessing the socio-technical systems that exist within the co-housing context. The research aims to look at the influence new technology has over the co-living society, data to be collected from existing literature will be on existing co-housing projects case studies, physical building characteristics and new innovations in the co-housing context. A theoretical framework will be adopted to further understand the different forces that come to play when a new technological system penetrates into a society. This step will aid in answering the second and third research questions.

The third step will involve gathering the final results from the first and second steps in order to form recommendations to answer the last research question.

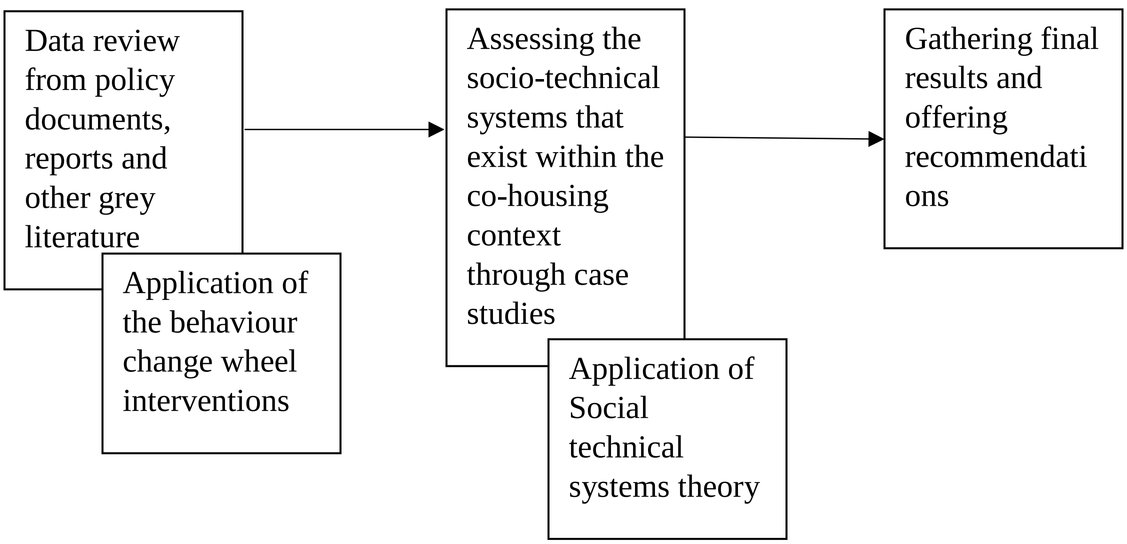

Figure 5: Conceptual framework: own creation

5. Dutch Energy saving Directives

This section looks into the different Dutch policies in place that are geared towards realizing energy efficiency in the context of co-housing, the aim of this section is to answer the first set of the research questions: *Which Dutch green building policies exist and how do they stimulate energy efficiency in co-housing projects? And which policy instruments does the government use to facilitate energy efficiency?*

Energy efficient strategies existing both at the EU and national levels commit to attaining the set energy saving targets. These directives facilitate the removal of barriers and promotion of energy efficiency in the built environment. Back in 1995 the Dutch government through the Dutch climate policy instituted that all new buildings must be certified in accordance to the *(EPN-(Energie Prestatie Norm).* The Dutch version of energy performance standards, the EPN is a directive aimed at reducing the carbon footprint resulting from the built environment, in addition the EPN is complimented with the energy efficiency coefficient (EPC) which is a tool bearing the minimum requirements for new buildings, these requirements must be followed to realize energy efficiency (Spyridaki et al., 2016).

The use of the EPC tool has been tightened with a focus of attaining the Nearly Zero-Energy Buildings (NZEB) level. This is a scheme to ensure all the building stock in the Netherlands have high energy performance with low or nearly zero energy requirements preferably from renewables sourced nearby or on-site("Implementation of the EPBD in the Netherlands," 2020). The NZEB ideology has three requirements which is the *Trias Energetica* as shown in figure 6 below

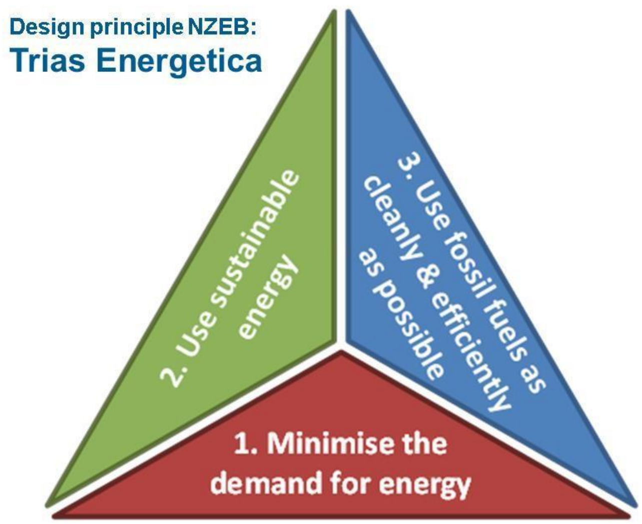

Figure 6 Trias Energetica (NZEB requirements) Source: Implementing the Energy Performance of Buildings Directive 2020

Fast forward to 2006, the Energy Performance of Building Directive (EPBD) was adopted by the Dutch government. The EPBD is a legislative tool constituted by the EU to push towards efficient energy performance of buildings. Articles from the directive were replicated into the Dutch national decree on energy efficiency (*BEG-Besluit Energieprestatie van Gebouwen)* where the BEG contains several ratifications like: the display and the minimum mandatory information to be displayed on the EPC tool, methods of calculating energy efficiency and agent requirements for certification schemes (Sunikka, 2006). Due to this replication, existing buildings started applying the EPCs in 2008 as energy labels, these new EPCs became compulsory tasked with not only outlining the energy performance of buildings but also the provision of spontaneous tips and information on energy saving prospects. The new decree on energy labelling was amended further as a mandatory requirement for rented buildings and those which are sold, however the provision of certificates would be voluntary (Spyridaki et al., 2016).

The energy performance coefficient is calculated based on the accumulative primary energy use of a building with a focus on lighting, heating and ventilation adjusted to the gross usable floor area and the energy from renewables within the building, with the coefficient values varying for different types of buildings. However as from 1st January 2021 the EPC was replaced by energy performance (EP) indicators which is expressed in (kWh/m2.year) unlike the EPC which was expressed in (MJ/m2.) ("Implementation of the EPBD in the Netherlands," 2020). Despite the change towards EP the use of EPC has proven fruitful in improving the energy efficiency of buildings as graphically described below.

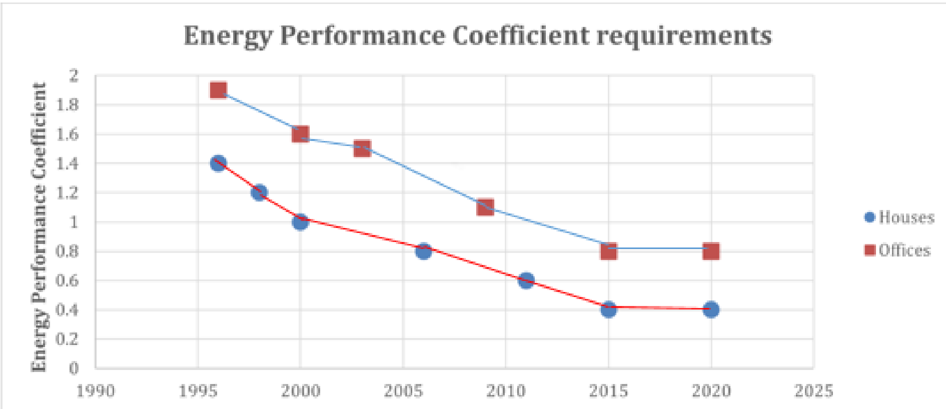

Figure 7 Change over time of the energy performance coefficient in new buildings Source: Implementation of the EPBD in the Netherlands, 2020

Table 2: **Required maximum values for the energy performance coefficient for different building typologies**

Building Typology	**Required maximum values for the energy performance coefficient (new buildings)**
Day-care centers	1.1
Prisons	1.0
Healthcare buildings with bed area (hospitals)	1.8
Healthcare buildings (other than with bed area)	0.8
Office buildings	0.8
Accommodation in lodging structure (hotels)	1.0
Accommodation not in lodging structure (conference facilities)	1.4
Educational buildings	0.7
Sports buildings	0.9
Retail buildings	1.7
Residential buildings	0.4
Mobile homes	1.3

The Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD) are the major tools of legislation in the EU that govern the adoption of energy efficient buildings. These directives promote energy efficiency for both new and old buildings through the certification of energy efficient buildings and facilitate approvals during the building's construction period (Visscher et al., 2016). The Dutch government also establishes national policies that local municipalities/governments are responsible for implementing. Home owners associations, housing cooperatives and local municipalities work in tandem to realize energy efficiency goals. The Dutch Association of Social Housing (Aedes) is the official body mandated to oversee the non-profit housing stock, where co-housing developments fall under. Whereas in the rental category both tenants associations/unions and social housing groups facilitate energy efficiency by voluntarily operating energy efficient programs (Tambach et al., 2010).

The Dutch government uses several instruments directly and indirectly to implement these energy efficiency policies, subsidies and incentive programs have been rolled out as a way of advancing more financing options (Ebrahimigharehbaghi et al. 2019) outlines a series of three main financial instruments/schemes adopted by the Dutch to stimulate energy efficiency; the Sustainable Energy Investment Subsidy (ISDE), National Energy Savings Fund (NEF) and the Homeowners Energy Saving Subsidy (SEEH). The NEF was entrenched in 2014 including incentive programs like the Energy Performance Incentive Scheme for the Rental Sector (STEP) to stimulate landlords to advance their energy efficiency ambitions in relation to their properties and the Energy Savings Fund for the Rental Sector (FEH) which facilitates the provision of low interest rate loans to landlords (RVO, 2014).

The Homeowners Energy Saving Subsidy (SEEH) which runs till the end of 2022 grants housing associations and homeowners the chance to apply for subsidies for floor/wall insulations and it also includes subsidies for maintenance and energy consultations (RVO, 2020a). The Sustainable Energy Investment Subsidy (ISDE) on the other hand enables property owners to acquire solar heat pumps and boilers at a subsidized price, latterly this subsidy instrument has extended to back home owners who are undertaking insulations in their projects (RVO, 2020b). The NEF on the other hand enables owners of apartments and private real estate to acquire tax-deductible loans of upto €25,000, this scheme is applicable for solar panels, can be used for solely acquiring solar panels (NEF (National Energy Savings Fund), 2020).

The Dutch government also provides provision for subsidized electricity costs for individuals who have installed small-scale solar PV, the net-metering scheme enforced in 2004 runs upto 2030 and enables those who have invested in solar panels to have a feasible payback period (IEA, 2020). Residential spaces that self-consume their own electricity are exempt from the sustainable energy surcharge levy and they are also cushioned from paying the energy tax. The subsidized cost of electricity is comparatively cheap to the standard electricity costs in the Netherlands, in the long-run this instrument has proven efficient in the past 10+ years and therefore mitigating the uncertainties that exist within the regulations (Ugarte et al., 2016).

Aside from the financial incentives, the Dutch government has rolled out a series of tax reduction schemes as an instrument to encourage more energy efficient developments, these schemes include; Surtax Renewable Energy- aimed at reducing taxes for home owners who are shifting from gas to electricity in order to promote sustainability, Energy Investment Tax Deduction (EIA) – this scheme deducts taxes for investments that are focusing on energy saving measures with an aim of propelling companies to invest in more energy saving ventures, Environmental Investment Tax Deduction (MIA)- for those who have invested in environmentally conscious investments, they can get upto 36% deduction of the amount invested, Depreciation of Environmental Investments (VAMIL) –gives investors freedom to choose how they would like their environmentally friendly investments to depreciate, reduced VAT rate-this applies for those who have installed insulating materials usually glass and exemption from energy tax for self-generated energy- individuals who have jointly generated energy from renewables through a cooperative are exempt from the energy tax. (“Implementation of the EPBD in the Netherlands,” 2020)

Co-housing falls in the social rental sector and over the years these initiatives have been on the frontline in realizing carbon-free homes and towards natural gas-free residential spaces, the aforementioned policy instruments apply to the whole sectors however a number of policy directives have been focused specifically for the social rental sector starting with the phasing out of natural gas and moving towards district heat connections where residential spaces are connected to insulated pipes that emanate from a central source of heat. Implementation of the EPBD in the Netherlands (2020) outlines efforts by the Dutch government to partly transfer the cost of energy efficient investments from the landlords to tenants in a way interlacing the split incentives between the users of the property and the investors. This is made possible by having a joint contract with the social housing associations to provide a framework that will work towards the improvement of the current social housing stock, other incentives that provide supplementary investments include the Renewable Energy Investment Subsidy (ISDE), energy performance fee and reduced Landlord Levy Sustainability Scheme.

Various programs are in place like the “Startmotor” program which prompts and stimulates extensive large-scale renovations in the social housing sector in a sustainable manner. This scheme aspires to realize 20-40% (TCO-integral cost reduction) from the prevailing cost by 2030, made possible by time-spreading innovation, demand bundling and collaborative standardization. This program has a target of making 100,000 dwellings gas-free for the period 2019-2023, as part of the climate agreement and the “Startmotor” program under the label ‘Renovation Accelerator’. This plan not only aims to realize more large-scale renovations but also seeks to attain increased productivity and innovation in the building industry. “Key principles in this include industrialization, standardization, predictable demand distribution across time, chain collaboration, procurement cooperation, and standardization. This indicates that the "Renovation Accelerator" serves a broader social and sectoral interest in addition to holding a prominent place within the Climate Agreement.”(“Implementation of the EPBD in the Netherlands,” 2020)

The government has also put in place the “Long-Term Renovation Strategy” LTRS which focuses on how the built environment can mitigate climate changes. It offers a clear picture of the variety of strategies used by the Netherlands to create a low-carbon built environment by 2050. The plan outlines some important ideas and offers a comprehensive overview of the Dutch commitment to the built environment. Additionally, it depicts the connection between current instruments which will operate in the coming years for improving the built environment in a sustainable manner.

The LTRS backs the Dutch policy, which consists of a variety of actions and a blend of themed and target cluster instruments as described in the illustration below

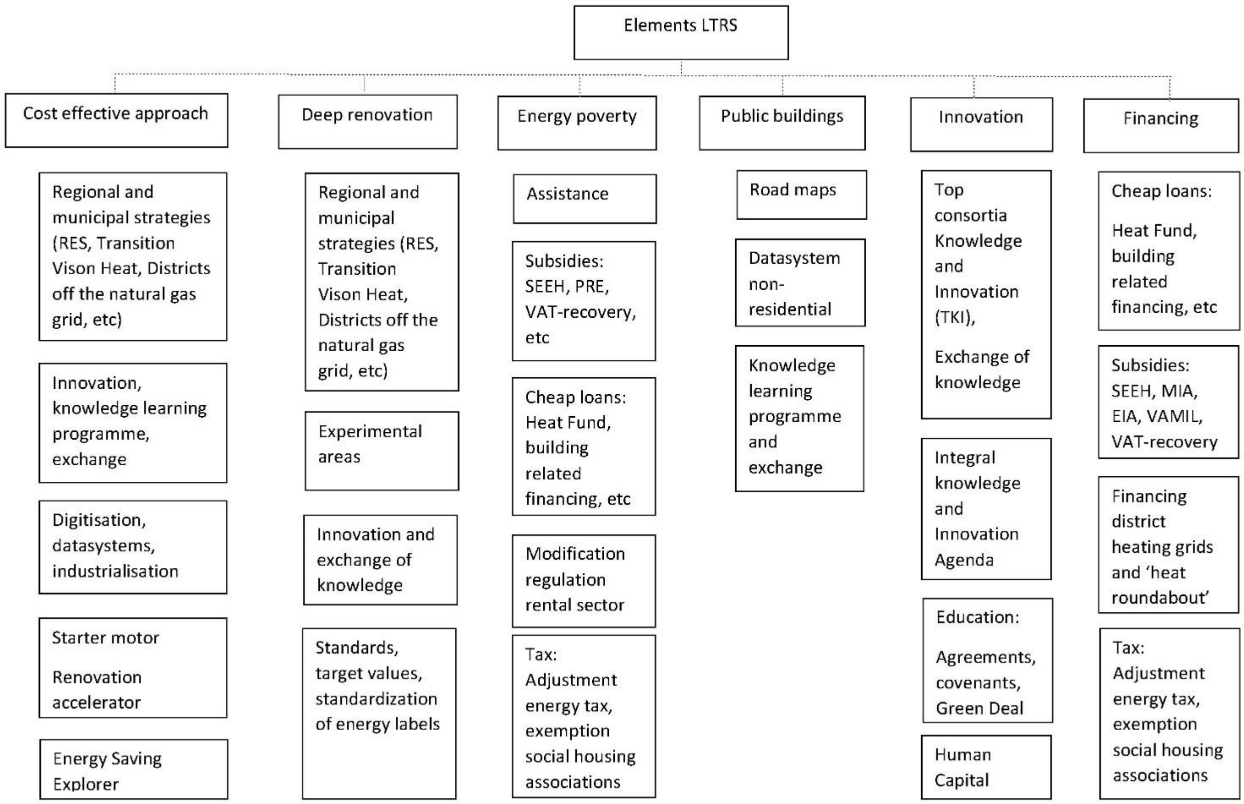

Figure 8 Fundamental policy strategies and measures Source: Implementation of the EPBD in the Netherlands, 2020

The government has also set aside informational instruments to spread the gospel of climate transition in collaboration with social groups and companies. One notable initiative is the "Everyone does something" campaign where individuals are encouraged to make sustainable decisions within their homes. The campaign allows people to contribute towards sustainability in every means possible no matter how small ranging from using renewables as a source of energy to reducing food wastage. The government has also initiated a training and innovation campaigns for the professionals in the real estate sector, these platforms exist to facilitate knowledge and idea sharing to boost innovations in the energy sector, such programs include: "The Sustainable Heat and Cold Built Environment Programme" which focuses on training professionals on how cold and heat can be supplied from sources which are sustainable and a training programme where professionals are trained on how conduct renovations in an extensive manner ("Implementation of the EPBD in the Netherlands," 2020).

The aforementioned financial instruments fall under structural interventions, these directives are also known as pull measures where environmentally friendly behaviour is encouraged by lowering prices. These policies are aimed at reducing the prices of energy efficient technologies, and through these schemes behaviour towards energy efficient developments has improved over the years. The measures are less intimidating because they lack coercion. Studies show that people typically see these measures as more acceptable than measures which penalize (L. Steg & Vlek, 1997).

Due to the fact that people frequently rely their decisions on mental shortcuts and habits, access to information alone does not always lead to a change in behavior. However since most of the projects are citizen-initiated with an aim of achieving a sustainable lifestyle most of the structural policies are relevant, the informational policies however do not have much impact as they are mainly focused on individual dwellings and not collective dwellings, co-housing initiators usually have the full information/idea as they involved in the projects right from the inception to final use.

In summary, the government has set aside financial and informational instruments to ensure energy efficiency in co-housing projects, the financial instruments consist of subsidies and tax deductions/exemptions, these instruments are implemented through a series of programs like; Sustainable Energy Investment Subsidy (ISDE), National Energy Savings Fund (NEF) and the Homeowners Energy Saving Subsidy (SEEH), Energy Savings Fund for the Rental Sector (FEH), the net-metering scheme, energy performance fee and reduced Landlord Levy Sustainability Scheme.

Tax reduction schemes include; Surtax Renewable Energy, Energy Investment Tax Deduction, Environmental Investment Tax Deduction (MIA), Depreciation of Environmental Investments (VAMIL), VAT refund and offsetting scheme for solar PV, Exemption from energy tax for self-generated energy, Heat fund, Stimulation Scheme for Natural Gas-Free Rental Homes, renovation accelerator. The information instruments include; “Everyone does something” campaign and the “Sustainable Heat and Cold Built Environment Programme”.

6. Case studies and mapping Co-housing

The following section detail the characteristics of a number of co-housing developments in order to understand design characteristics commonly found in co-housing that relate to energy efficient living with an aim of answering the third research question: *Which building design features are found in co-housing initiatives and how do tenants interact with these features to realize efficient energy use?* These cases were selected according to the following criteria: The first two projects De Kersentuin and Ecodorp Boekel were selected because they represent two of the most prominent co-housing projects in the Netherlands. De Kersentuin was also selected because it is situated in Utrecht, which is the fourth largest city in the Netherlands, also it is one of the most successful self-initiated projects by citizens in Utrecht.

The third project Iewan-straw district in Nijmegen was selected because despite Nijmegen being a small city they have extensively initiated a lot of co-housing projects a total of 66 which is more than the bigger cities like Eindhoven and Rotterdam, other two projects were selected randomly from Nijmegen and The Hague. These projects were also selected because all five employ different eco-friendly building materials like straws for the Iewan-straw district project and hemp lime which has been used in Ecodorp Boekel. These five samples are all citizen-initiated with the tenants all with a sustainability goal in mind unlike other projects which did not develop from a sustainability background. With the aforementioned characteristics it is clear that the five case projects will sufficiently answer the third research question, looking at more cases would shift the focus towards the design features neglecting the policy analysis.

6.1 Co-housing design

Co-housing designs usually vary depending on the fundamental aim/goal sought to be achieved, projects can be designed with an aim of providing homes for the elderly as a way of providing love and care, projects can also be based on cost efficiency both for the tenants and developer since the concept of shared space is cheaper for both parties. Co-housing projects can also be designed with an environmental focus, meaning the physical orientation structure will be focused to ensure maximum use of natural resources, however most co-housing initiatives integrate the day-to-day activities into the initial plan meaning the arrangement and size of spaces is dependent on what tenants do daily as a routine (Jarvis 2012).

Figure 6 below illustrates the contemporary design that most co-housing initiatives in Europe adopt, the design shows the standard common utilities, however the spatial planning varies for different initiatives. Common features include jointly shared spaces both indoor and outdoor, terraced homes and clustered shared parking spaces, most co-housing designs integrate soft boundaries and intermediate spaces as a way of connecting the tenants with the common spaces and also in return secures privacy for the tenants(Tummers, 2017).

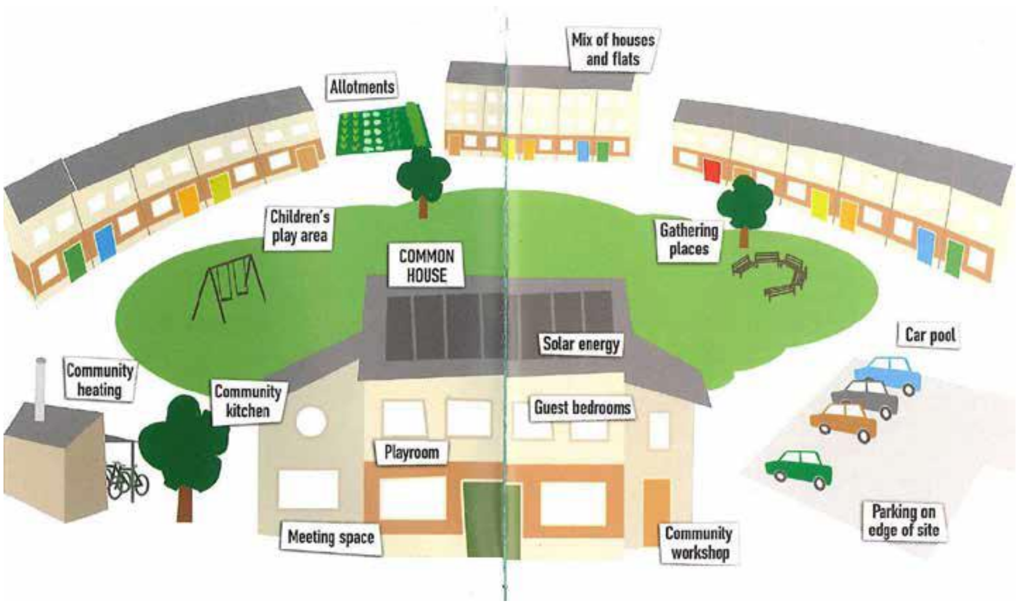

Figure 9 Co-housing design adopted from (Tummers, 2017)

Figure 7 below illustrates all the co-housing developments in the Netherlands, in total there are over 800 co-housing projects in the Netherlands. These projects are spread all over the country however the larger cities have more projects than the smaller ones, Amsterdam has the highest number of co-housing projects with 102 projects, Nijmegen 66, Utrecht 62, Den Haag 53 and Rotterdam 38, Nijmegen is a smaller city compared to others but they have extensively initiated a lot of co-housing projects more than a cities like Eindhoven and Rotterdam (Kat. M, 2019).

Figure 10: Map of all registered co-housing projects in the Netherlands (Kat, 2019).

6.2 <u>Ecodorp Boekel</u>[1]

Ecodorp Boekel is a co-housing initiative ran by a cooperative situated in the municipality of Boekel, the project's built space sits on a 1.2 hectare piece of land consisting of 30 rental homes, six informal care homes, workshops, office spaces, a tree house hotel, a community center, education center and a knowledge center. These improvements are all climate-adaptive and

[1] https://www.ecodorpboekel.nl/

climate-positive, the former is in line with the Dutch national climate adaptation strategy. A strategy set out to increase adaptability and innovation in the wake of extreme weather conditions. The project has installed green roofs as a way of adapting to hailstorms and extreme heat, excess water from extreme rain and water from the roofs is drained into water tanks installed in the project, the water storage aid during dry periods.

The project strives to be climate positive by building with materials that are organic and renewable. The homes are built with hemp lime, which is an innovative walling material that is organic and possesses hygro-thermal properties, meaning the material can absorb, store and release moisture and heat therefore reducing energy costs for heating and cooling. The underground power cables and heating pipes are also made of recycled waste.

Figure 11 below shows the floor plan of the project

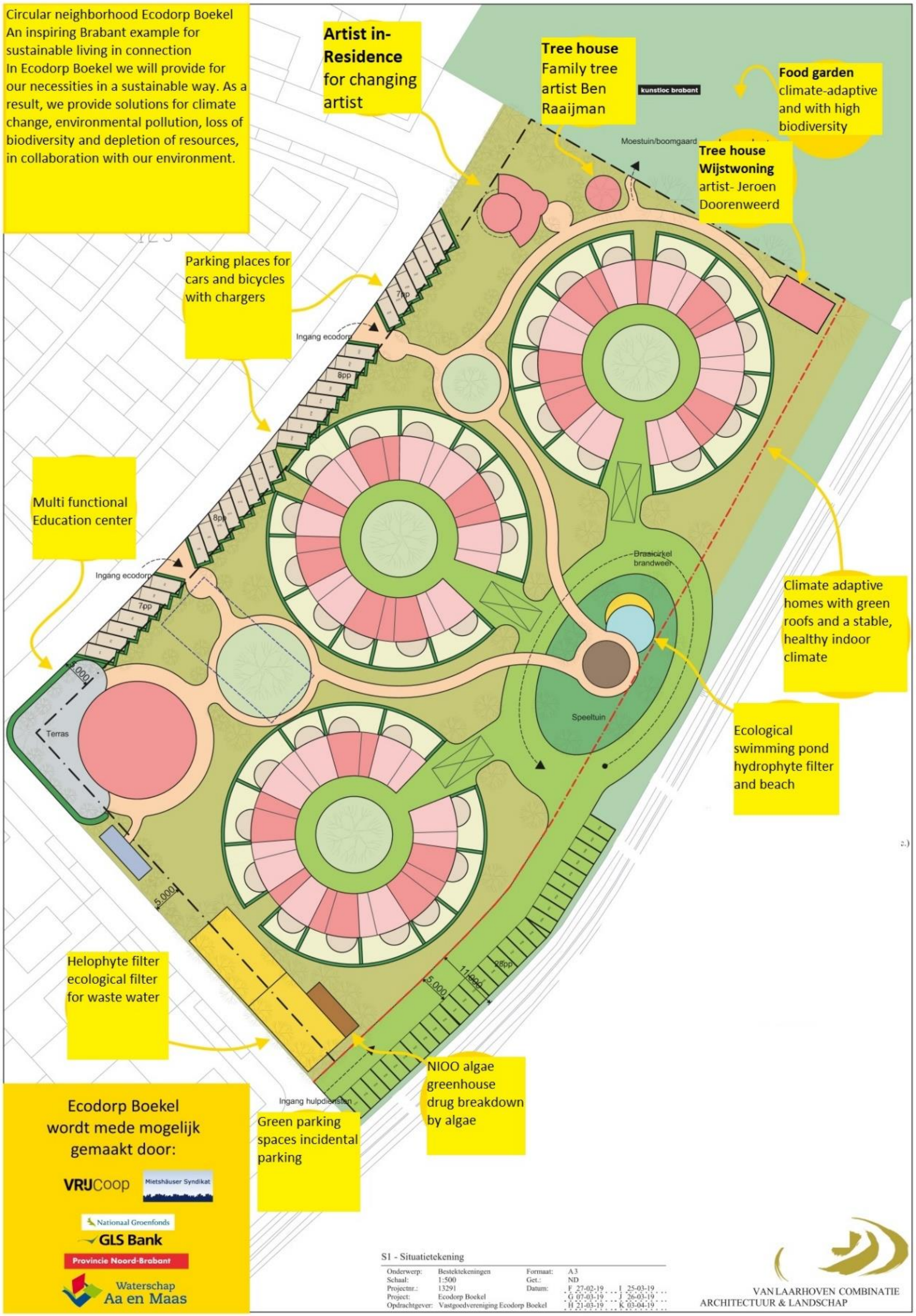

Figure 11 Ecodorp Boekel Master plan

The project seeks to offer remedies for all the 17 Sustainable Development Goals (SDGs) through environmental management, through these solutions the initiative is able to produce their own food, water and energy. In the energy context the project has given focus to realize the following SDGs

SDG7: Affordable sustainable energy

Energy is saved in the project through the use of direct current in the homes and extensive insulation of the homes. Since the project produces its own energy, each home acts as a mini power plant, this is so because the units produce more energy than what is needed. The heat absorbed during summer is stored and used throughout the year. To reduce the emission of CO_2 two remedies are implemented to mitigate this phenomenon;

1. Lowering energy consumption.

During the day solar panels installed on site produce direct current which is stored in batteries. This stored energy provides electricity for home appliances, the unused energy is directed to the grid after being converted into alternating current. Energy savings is not only realized through the use of direct current, the homes are extensively insulated thus saving on heating energy, a ventilation heat pump is installed to heat the water from the taps and also to heat the floors. The project through innovative programs is also designing motion sensor lampposts that light only when it detects a person cycling or walking.

2. Shift towards renewables.

The homes are designed to be energy positive and through the installation of solar panels clean energy is achieved as well as production of excess energy which can be stored. The heat through new innovations is stored in basalt batteries for later use.

SDG9: Industry, innovation and infrastructure

The homes are fitted with autonomous sensors which track all indoor and outdoor conditions to provide perfect and comfortable living conditions using the least amount of energy possible, these sensors even have the capability of tweeting information.

SDG11: Sustainable cities and communities

Ecodorp Boekel through the communal meetings and sustainable social interactions enables idea sharing and therefore creating a community of like-minded individuals working towards the sustainability goal.

SDG12: Responsible consumption and production

The tenants in the project produce their own energy, food and water on site through these initiatives a community of responsible production and consumption is created.

SDG13: Climate action

Through the use of eco-friendly materials for construction, renewables for energy production and the provision of climate-adaptive homes the project is on the forefront to reduce CO2 emissions and protect the environment.

6.3 De Kersentuin[2]

The Kersentuin is a particularly different and unique precinct within Utrecht-Leidsche Rijn. The project is an ambitions co-housing initiative with green, social and sustainable aspirations. The project (see figure 9) was established in 1995 by a group of individuals who had ambitions for an ideal and optimal sustainable living space (Kiesel, 2018). This initiative could not be established by the existing developers as at that time prompting the residents to create it by themselves, the idea was in line with the municipality's sustainable goals and therefore it provided land at a subsidized price for the construction of the project.

[2] https://kersentuin.nl/

Figure 12 Co-housing project Kersentuin from an aerial view (https://kersentuin.nl/)

The project was finally commissioned in 2003 with backing of the municipality and the Dutch housing corporation also known as *Portaal*. In line with the sustainability and efficiency goals the buildings are all constructed with eco-friendly recycled materials like wooden gutters, recyclable polyethene used for the electricity pipes and plastic water pipes. The building's exterior rear facade is covered with ceramic tiles and masonry finish for the front with the façade clad with thermally preserved softwood coupled with pressed rock wool. There is also special provision for solar panels, well-balanced ventilation systems, wall heating and exceptional thermal insulation. The project boasts of three community gardens each with a different concept, there are 94 dwellings, 28 being social housing managed by *Portaal* while 66 are privately owned homes, there are nine home designs to choose from with the freedom of choosing how to divide them. Other facilities include the parking garage, a project house and communal spaces both outdoor and indoor.

The project hosts a diverse set of tenants including families and singles, old and young, disabled and the able-bodied. Due to this diverse set of tenants the dwellings vary in sizes and designs from “work from home” houses, small apartments, large family dwellings, and the disabled stay in single-storey dwellings.

Energy measures

Aside from using recyclable sustainable materials the project has implemented several energy efficiency measures in line with their sustainability goals, these energy measures include;

- Large living room windows to allow maximum natural light and reduce electrical lighting.
- Use of (light-emitting diode) LED lighting in common areas like the parking spaces and corridors, these bulbs are more efficient than the normal incandescent lighting(upto 90% efficiency).
- Solar panels are installed on the south-facing roof for maximum sunlight absorption.
- The ventilation system is supplied with natural air and let out mechanically through an exhaust, this system is controlled by a computer regulating the indoor conditions depending on the wind pressure and the number of people in the room.
- The dishwashers and washing machines have hot fill connections meaning water getting into the machines is hot already and usually stored in the house from the solar panels, this in return saves on the energy that would otherwise be used to heat cold water by the machines.

The buildings EPC value was 0.7 back in 2003 with the required EPC being 1.2, the insulation values of the buildings are tabulated below

Table 3: Building required EPC values

Building feature	**Minimum Required Value**	**Buildings’ feature value**
Ground floor	R-value ≥ 3.5 m_2.K/W	4.0 m2 K/W
Roof	R-value ≥ 6 m_2.K/W	5.0 m2 K/W
Facade	R-value ≥ 4.5 m_2.K/W	3.4 m2 K/W

Through the provision of communal spaces and facilities most activities within the project are usually done communally, this is also encouraged by the cluster design of homes, tenants get to interact with each other. The gardens and project house as shown below in figure 10 and 11 respectively serve as the meeting places, with these facilities, the tenants' social cohesion is strengthened. Decisions and new ideas regarding sustainability goals are made through these meetings, problems are solved and the tenants also get to have fun with each other. For instance the initiative of solar installations and motion-sensor street and parking lighting was collectively decided upon by the tenants and the purchases were made collectively. The tenants also get to share the playing utilities, the laundry room and the parking garage, through this communal sharing the energy consumption reduces compared to single use of the facilities.

In terms of mobility the residents get to car-pool with their fellow neighbors through a collaboration with a car-pooling platform, children's cargo bikes and adult cargo bicycles are also available for sharing as a way of reducing GHG emissions and a way of building healthy social relations.

Figure 13 One of the communal gardens in the project

Figure 14 Kersentuin project house

6.4 Iewan-Straw district Nijmegen[3]

The Iewan-straw district in Nijmegen is a unique co-housing project boasting of 24 social dwellings all built with straw, wood and clay, it is the biggest straw structure/building in the Netherlands. The idea of the project was coined in 2009 by a group of people who shared the idea of communally living in a sustainable way. "Initiative Group Ecological Living Nijmegen" or Iewan in short collaborated with two housing associations Talis and Gelderland, Vastbouw; a construction company and full support from the province of Gelderland to realize the co-housing dream that stands now. The project commenced in March 2014 and was completed in 2015, the residents themselves took part in the construction with the help of volunteers. The walls are

[3] https://www.iewan.nl/

made of timber frames and straw clad with a clay plaster. The project was erected with eco-friendly materials which could also be applied in reducing the energy consumption.

Figure 15 Rendered impression of project Iewan from an aerial view

Figure 16 Straw and wood construction

The project has 24 residential dwellings each with a kitchen and a bathroom divided as listed below;

- 6 double houses
- 3 living groups: 1 for the young adults and 2 for adults
- A multifunctional hall
- 10 single-person homes which includes two single-storey homes reserved for the elderly
- 3 family homes
- 2 homes for single-parent families

Workspaces are also available where residents can rent them as studios, offices or a practice space.

The project has implemented 3 core values to be followed as a way to realize sustainable living, these values are the guiding principles right from the start of the project to the use, the core values are;

1. **Social and communal**- Residents at Iewan live as one community, they participate in all activities, share facilities and care for the environment collectively, the tenants always meet at the multi-functional hall where they have joint activities and discuss new sustainable initiatives.
2. **Sustainable and ecological**- The focus of attaining the Nearly Zero-Energy Buildings (NZEB) level requires that the building stock in the Netherlands should have high energy performance with low or nearly zero energy requirements preferably from renewables sourced nearby or on-site. Through this ambition the project prioritizes the use of eco-friendly materials, new innovative energy approaches and avoiding the reliance on fossil fuels.
3. **Educational and open image**-The project also seeks to educate masses on their sustainable practices/solutions as a way of raising more awareness for people to develop more similar initiatives and also convincing the authorities and investors to jump on board and support such sustainable grassroots initiatives. The project also strives to give an easy access to anyone who wants to learn from them, these two aims are made possible through training programs, tours around the project and open days.

Energy efficiency measures

- Energy supply in the project is dominantly through solar panels on site as shown in figure 14, electric cookers and induction stoves are used for cooking discouraging the use of fossil fuels(gas), LED bulbs are used for lighting and energy efficient appliances are used and encouraged.

Figure 17 Solar panels installed on the roofs of the houses

- The compact clustering of houses not only promotes social cohesion but also promotes energy efficiency as this reduces the amount energy required for heating, the sharing of spaces and joint living reduces the aggregate surface area needed to be heated.
- Water purification in the project does not consume any energy as the filtration process is fully environmental friendly through the use of a helophyte filter, a system where waste water is passed through reed plants where bacteria in the roots treat the water, the treated water is re-used as flushing water.
- The buildings receive maximum natural lighting due to its southward facing orientation, this reduces the use of electric lighting during the day and also the building material retains heat therefore provides insulation.
- During summer, the houses do not consume energy to cool down, instead there is enough roof overhang prevents overheating.
- The water in the taps is heated using the ventilated air through a system of heat recovery.
- The tenants share cars, vacuum cleaners, workshop, kitchen, living spaces, laundry rooms/machines and even maintenance tools, this collective action in activities and sharing reduces aggregate consumption of every resource including energy as less surface area is covered.

The culture of sharing and communal participation not only ensures sustainability but also provides a platform for sharing ideas, knowledge and motivation, this in return stimulates more innovations and similar initiatives. Through this phenomenon the life cycle costing of the buildings is reduced as maintenance and management is in-house rather than outsourcing these services, with low servicing and management costs, housing provision becomes easy and cheap across all demographics.

Table 4:Summary of Community design strategies to promote energy efficiency.

STRATEGIES	Ecodorp Boekel	De Kersentuin	Iewan-straw district
Resource sharing	A community center used as an education and a knowledge center, communal gardens, workshops, office spaces, excess water stored in tanks	Playing utilities, laundry room, community gardens, parking garage, communal purchases	Multi-functional hall, car-pooling, vacuum cleaners, workshop, kitchen, living spaces, laundry rooms/machines, vegetable garden and even maintenance tools.
Self-management	In house maintenance and management of the common spaces	Managed by a housing cooperation	In-house maintenance and management (no outsourcing)
Design aspects	Clustered into three main buildings to reduce surface	Clustered multi-storey units	Compact clustering of multi-storey houses built with straw bales self-built by the tenants, contains buffer zones and semi-communal spaces.
Engineering aspects	-Green roofs, -hemp lime construction, -underground heating pipes made of recycled waste, -collective solar use with battery storage, -autonomous sensors that monitor indoor and outdoor temperature conditions - motion sensor lampposts	-Façade clad with recyclable polyethene thermally preserved softwood -collective solar panels, -well-balanced ventilation systems, -Large living room windows -Use of LED lighting -ventilation system is supplied with natural air -hot fill connections for dishwashers and washing machines	-Collective solar panel installation, -energy efficient appliances, -roof overhang prevents overheating, -water heating through heat recovery system, -southern facing windows, -on site water purification

Learning	Communal meetings for idea sharing and innovations	Gardens and project house are used as meeting spaces where problems are solved and new ideas implemented communally	Tenant- build, idea sharing platform, informational workshops and tours, in house management

6.5 Central living Houtwijk[4]

Central living Houtwijk is a co-housing project situated South-west of The Hague, this form of communal living was commissioned in 1985 following a series of negotiations and planning between the housing association, the municipality and residents who had a common interest. Residents of this initiative jointly manage and share the existing facilities however each resident occupies their own individual apartment. The project houses a total of 85 residents within 49 households all clustered to form an openwork square shape encompassing a courtyard as shown below on a Google satellite-view map.

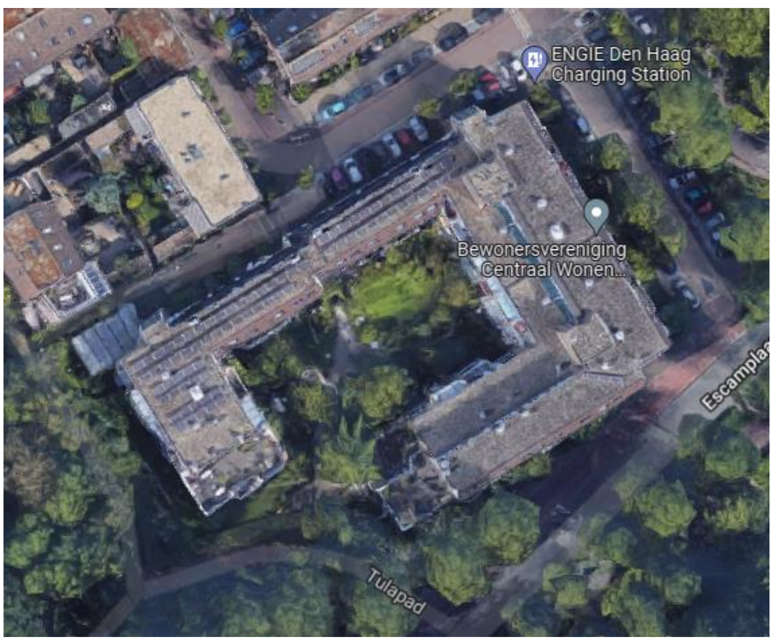

Figure 18 Google satellite-view map of Central living Houtwijk, Source: Google Maps

[4] www.cwhoutwijk-nl

The 49 housing units consist of 1,2,3,4 and 5 room apartments occupying three floors with each apartment equipped with a kitchen, bathroom and a toilet. With this diverse provision the project houses both the young and old including families and single people. The project complex offers a total of eighteen communal areas consisting of a garden, bar, cinema, workshop, creative hall, quiet room, terraces, laundry room, sauna and guest rooms, these facilities are used for fun joint activities and social community development within themselves through meetings and parties. To improve the social cohesion and community development social gatherings like breakfast meetings are scheduled on a regular weekly basis. Through these interactions the residents have ensured that sustainable living is upheld. Through these meetings together with the housing association the tenants were able to agree on installing solar panels as a move towards renewables.

The community strives to realize sustainable living through a number of energy saving initiatives:

- Right from the construction, all the floors, roofs and walls were insulated to reduce energy use for heating and cooling,
- Water is heated via a HR++ (High-return) central heating boiler instead of installing individual boilers for each tenant

Through co-living, the tenants' social involvement on matters sustainability coupled with joint environment conscious mentality has yielded combined efforts of reducing energy use throughout their day-to-day activities. These activities include:

- Tenants come together at the cinema hall to watch their favorite programs reducing energy consumption from the use of individual television sets.
- Tenants are sectioned into different groups where once in a week they jointly cook and eat together at the common kitchen, subsequently the groups tasked with different roles including maintenance of the machines, garden and the building itself.
- Energy for the common areas is sourced from solar panels installed on the roofs through a subsidy from the municipality, under a "solar panels" scheme. Initially the plan was to install a windmill for the energy but the plan failed.

Figure 19 Solar panels installed on the roof of project Houtwijk

6.6 Residential Community Eikpunt[5]

This is a special co-housing project in Nijmegen which uses behaviour decision making techniques through meditation and spiritual connection to self, to each other and towards the earth as a means to building and strengthening communal ties. The project boasts of nine owner-occupied homes and forty rental homes and was officially conceived in 2009.

Figure 20 Residential community Eikpunt

[5] www.woongemeenschapeikpunt.nl

The realization of the project was guided by four pillars namely:

- Silence and Reflection: The community strives to build better relationships towards themselves and the environment through meditation, the residents take silent breaks inside a meditation center within the project's compound. Through these silence and reflection sessions community members are able to communicate better to one another and reflect on the impacts their activities have on the environment.

Figure 21 Meditation hall

- Community building: The housing units are clustered together with an aim of reducing private space and appreciating more communal spaces, this design feature coupled with meditation and reflection, stimulates the act of sharing within the residents. Residents get to undertake several activities together as a group like celebrations, gardening, cooking, laundry and maintenance of facilities
- Multi-generational living: This project accommodates all age groups and all demographics including the disabled and older people who need care and support, providing a dynamic living space for both groups who would otherwise be lonely living alone
- Ecology and sustainability: To ensure efficient energy use and sustainable practices the project has employed a number of strategies to ensure that the living surroundings are environmentally friendly as possible, these practices include:

- The walls of the housing units are constructed using natural organic materials like hemp-clay, straw and wood with double-shell insulation, triple glazed windows and extra insulated doors. These construction methods reduces the total amount of energy used for cooling and heating the spaces.
- Communal spaces like bike sheds, laundry rooms, communal washrooms, guest rooms, communal storage room and work spaces are provided as way of reducing aggregate energy usage.
- Solar boilers are used to provide hot water at the same time regulating the heat in the housing units via a heat pump, energy efficient technologies like LED lights, smart ventilation systems and energy efficient appliances have been installed and are encouraged.
- Water purification does not require a lot of energy as reed beds are used as a filter, gray water is also recycled and used for washing and watering plants.
- Transportation and purchase of household commodities is pooled reducing the amount of cars being used, hence saving on money and energy.

7. Summary findings: Synthesis of the top-down policies and bottom-up community designs in Dutch co-housing.

This chapter is devoted to synthesizing the policy (sub question 1 and 2) and co-housing/community design (sub question 3) knowledge that has been produced in the previous sections. In relation to the first objective which was to understand how Dutch building policies stimulate energy efficiency focusing on co-housing initiatives, the research found that the Dutch government has set out a range of initiatives with a variety of target cluster oriented instruments and thematic instruments. These instruments are effected for both new buildings and existing ones and apply to all sectors including the social housing sector where co-housing falls into, however the social housing sector has a number of its own specific custom policy instruments. These policies accelerate the move towards a built-environment which is carbon free.

Investment behavior and habitual behavior are the two main categories of energy-related behavior. Occasionally, people engage in investment behavior, which usually entails the adoption of new technology or the purchase of new appliances. Routine actions, such as turning off the lights while leaving a room, are examples of habitual behavior. The behavioral modification programs that were assessed attempted to modify both types of behavior, often within the same program, despite the fact that each type of behavior is associated with unique factors and requires unique interventions.

Human behaviour towards energy efficiency can be influenced by policy interventions, these interventions can be classified into two: informational and structural. Informational interventions are effected with an aim of motivating people towards energy efficiency through the provision of information relating to energy saving norms, energy efficient technologies including provision of feedback to the aforementioned topics. Structural interventions adjust the conditions for household decision-making, these interventions include financial instruments like taxes and subsidies. The informational interventions can be further classified into two: consequent and antecedent interventions, the former which is mainly through energy labels influences behaviour determinants, while the latter provides feedback/ information after the behaviour has been executed.

The exploration of the BCW clearly indicates that even the basic initiatives for efficiency and the use of renewable energy require radical changes in human behavior related to energy. Therefore the implementation of the policy directives in a bid to realize sustainable and green societies requires radical changes in human behaviour. From the research it is evident that the interaction between the top-bottom policies and bottom up communal living realities has come a long way in facilitating energy efficiency behaviour, this interaction clearly manifests in co-housing initiatives propelling it to be an innovator of sustainable environmental technology and housing.

Improvement and implementation of policies in the energy efficiency domain requires a focus on the end-user of a project behaviour, a plethora of frameworks regarding change of behaviour guides policy makers to settle down on a policy. The behaviour change policy wheel theoretical framework is validated by the evidence of efficient energy use in co-living spaces facilitated by financial and structural policy instruments adopted by the tenants.

Based on the findings in all the five case studies and it is evident that the co-housing concept penetrates into the society as a new technology/way of life with new technical changes. The community in return undergoes social changes just as seen from a socio-technical systems theory perspective. Energy transition will be successful in a society if the two main components of a socio-technical system are included that is: a clear set goal is set by a community people and constant feedback.

An innovation must be embedded into various heterogeneous environments such as the user environment, policy environment, and the business environment, in order to successfully launch it, hence the reason why most co-housing projects take more time to be realized than others as it brings about change. A socio-technical perspective broadens the focus beyond energy-efficient technologies to include culture, policy environment, social norms, infrastructure, markets, and practices.

8. Conclusion and recommendations

(WCED, 1987) defines sustainable development as “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" the co-housing concept is pegged on sustainable behaviour and through this sustainable behaviour social cohesion is created. Residents of these initiatives come together with a common goal of sustainability, it is through this common goal that motivation is boosted within the initiators, throughout the years these projects have pioneered sharable, sustainable and livable communities.

This research was geared to realizing the effort put by the Dutch government to realize energy efficiency in the context of co-housing projects and also to get to understand the bottom-up approach initiatives developed by co-housing initiators to achieve energy efficiency. From the research we are able to note that, through the climate agreement the Dutch government has ambitious plans to decarbonize the built environment with cooperation from all sectors, these ambitious goals by the government is made possible through a series of policy interventions both structural and informational that elicit behaviour change towards energy efficiency. These policies are effected to ensure that buildings attain the NZEB requirements through several financial and information instruments, local municipalities are also playing an active role to promote co-housing initiatives by providing land which these projects are developed on.

Based on the policy and case study findings it is worth noting that the co-living initiatives sampled not only depend on their societal aspirations of achieving green societies but also with the assisted help of policy instruments that push for energy efficiency. Through several programs discussed earlier we are able to note that through the collective nature of co-housing initiatives societies are able to come together and combine the policies already in place with the collective nature of such societies, through such synthesis societies are able to achieve sustainable greener lifestyles not forgetting new innovations.

The research was also able to look at five different case studies to understand how co-housing tenants and initiators design co-housing projects, live and work together collectively to realize energy efficiency. Through social cohesion, tenants of co-housing projects are able to adapt to new lifestyle changes characterized by resource sharing, in addition all the five case studies have incorporated different eco-friendly building materials with different construction designs however social cohesion is similar in all five, tenants in these projects share spaces, cars, ideas and participate in communal activities with an aim of reducing energy consumption, not only do they realize sustainable consumption but also sustainable production, from the case studies this thesis has been able to show that just like a sociotechnical system the onset of a new technology/regime prompts a community to change its social behaviour with a new concept of sharing resources taking course.

Based on the findings of all the five cases and policy evaluation we can observe that as much as the government is using the BCW to settle on policy intervention through subsidy programs the effort is not sufficient. Following the BCW steps the Dutch government should first identify the target market to embrace sustainable living for example student housing as a target since most student housing is characterized by sharing of resources, new initiatives combining student housing and co-housing features should be developed as another way of realizing greener societies, student housing already has the resource sharing background however most are not developed with a direct aim of realizing energy efficiency therefore a hybrid system should be developed to promote more sustainable lifestyles.

The study was able to establish that most of the co-housing initiatives are tenant-initiated and therefore as a recommendation the government should take a steering role in developing more co-housing projects instead of only offering a supporting hand to the already developed initiatives.

To better understand these results' implications further research should be done to compare the different energy usage of a co-housing project and a standard residential green building. The study has inherent limitations due to lack of crucial interviews, the results were based on desk research however interviewing policy experts would do more justice to the topic, therefore further research on this should also include policy makers or active stakeholders in policy formulation.

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