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Profiling home occupants' comfortand energy-related behaviours with mixed methods

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Marco A. Ortiz

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TOC

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TOC

Home Occupant Archetypes

Profiling home occupants' comfort- and energy-related behaviours with mixed methods

Dissertation

for the purpose of obtaining the degree of doctor
at Delft University of Technology
by the authority of the Rector Magnificus, prof.dr.ir. T.H.J.J. van der Hagen
chair of the Board for Doctorates
to be defended publicly on
Tuesday, 17th of December 2019 at 12:30

by

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TOC

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To my Parents

TOC

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TOC

Contents

List of Tables 16
List of Figures 17
Summary 19
Samenvatting 23
Sommaire 29

1 Introduction 35

1.1 Background and problem definition 35
1.2 Aim of the study 40
1.3 Research questions 40
1.4 Methodology 43
1.5 Outline of thesis 46

PART 1 Literature Review + Development of Questionnaire

2 Introducing Comfort, Energy, and Behaviours 53

A review of comfort, health, and energy use: Understanding daily energy use and wellbeing for the development of a new approach to study comfort

2.1 Introduction 55
2.2 Materials and Methods 55

2.3 Results 57
2.3.1 Comfort 57
2.3.1.1 Comfort definitions by discipline 57
2.3.1.2 Evolutionary Biology, Emotions, and Behaviour 59

2.3.1.3 Environment and Health 61
2.3.2 Energy in Buildings 63
2.3.2.1 Energy and Behaviours 64
2.3.2.2 Health and energy 67

2.4 **Discussion and findings** 68
2.4.1 Narrow view of comfort 68
2.4.2 Gaps in knowledge 69

2.5 **New directions** 70
2.5.1 Conceptual Framework 70
2.5.2 Methodological Framework 71

2.6 **Limitations** 72

PART 2 Validation of Questionnaire, Analysis + Development of Clusters

3 Questionnaire testing, validating, and preliminary results 81

Proof-of-concept of a questionnaire to understand occupants' comfort and energy behaviours: First results on home occupant archetypes

3.1 **Introduction** 83

3.2 **Method** 84
3.2.1 Questionnaire 84
3.2.2 Instruments 86
3.2.3 Study design 88
3.2.4 Data management and analysis 88
3.2.5 Clustering 89

3.3 **Results** 90
3.3.1 General characteristics of respondents & Participation rate 90
3.3.2 TwoStep Cluster analysis and Validation 90
3.3.3 Description of identified Archetypes 93

3.4 **Discussion** 106
3.4.1 General 106
3.4.2 Limitations and future research 108

3.5 **Conclusions** 109

PART 3 Enhancement of Clusters with Interview Data + Building Features Data

4 Integrating qualitative and quantitative research to develop the final archetypes 115

Developing home occupant archetypes: First results of mixed-methods study to understand occupant comfort behaviours and energy use in homes

4.1 **Introduction** 117

4.2 **Methods** 120
4.2.1 Study design 120
4.2.2 Questionnaire (quantitative data) 121
4.2.3 Field Study (mixed data) 122
4.2.3.1 Qualitative field study: Interviews 123
4.2.3.2 Quantitative field study: IEQ monitoring, building features, and energy readings 123
4.2.4 Data cleaning and analysis 124
4.2.4.1 Interviews: text mining. 125
4.2.4.2 IEQ, building features, and energy readings: statistical analysis. 125

4.3 **Results** 126
4.3.1 Cluster results 127
4.3.2 Interview text mining 130
4.3.3 IEQ and energy readings 131
4.3.4 Final Archetype descriptions 136

4.4 **Discussion** 139
4.5 **Conclusion** 142

PART 4 Development of the final Archetypes

5 Using focus groups data to finalize the Archetypes 149

Substantiation of Home Occupant Archetypes with the Use of Generative Techniques: Analysis and Results of Focus Groups.

5.1 **Introduction** 151

5.2 **Materials and Methods** 154
5.2.1 Participant selection 154
5.2.2 Data analysis 157
5.2.2.1 Transcriptions 158
5.2.2.2 Affinity diagrams 160

5.3 **Results** 161
5.3.1 Affinity diagram categories 163

5.4 **Discussion** 167
5.4.1 Practical significance 169
5.4.2 Strengths and limitations 170

5.5 **Conclusion** 170

6 Conclusion and recommendations 175

6.1 **Introduction** 175

6.2 **Answers to the Research questions** 176
6.2.1 Answer to the main question 180
6.2.2 Archetypal design parameters 185

6.3 **Limitations** 186
6.4 **Future process recommendations** 188
6.5 **Future research recommendations** 189
6.6 **Implications** 190

PART 5 Appendices

Appendix A Questionnaire 196
Appendix B Tables pertaining to Chapter 2 216
Appendix C Field Study 221
Appendix D Tables pertaining to Chapter 4 232
Appendix E Sensitizing Booklet 240
Appendix F Meaning of energy use at home 246
Appendix G Ideal Home Experience 250

Curriculum Vitae 255
List of publications 259

List of Tables

2.1 Research keywords 56

3.1 Questionnaire sections and description of instruments upon which they are based 85

3.2 Constructs and related Items retrieved from literature relating to psychosocial and physiological comfort 86

3.3 Final Solution variables and predictor importance 92

3.4 General Characteristics 93

3.5 Health and Symptoms 95

3.6 Emotions towards the home 96

3.7 Affordances: Elements of the home environment necessary to achieve comfort. 96

3.8 Locus of Control 97

3.9 Attitudes towards energy and energy consumption 99

3.10 Habits 99

4.1 Definitions of behavioural constructs included in the questionnaire 122

4.2 Distribution of groups of respondents 126

4.3 Variables composing the final model (Mean (SD)). 128

4.4 Personal and building characteristics with statistically significant differences between clusters and their p-value per archetype 129

4.5 Percentage of positive sentiments per topic discussed and means per category per archetype 130

4.6 Energy consumption readings per archetype (m^3 for gas and kWh for electricity in 1-month period) 132

4.7 Temperature of “preferred” locations with iButton’s per Archetype and Participant and outdoor temperature in degrees Celsius (1-week period) 133

4.8 Carbon dioxide and relative humidity per Archetype and Participant (24-hour period) 134

4.9 Summer-related energy variables from building checklist per archetype*. 135

5.1 Key archetypal characteristics according to cluster analysis and field study. 153

5.2 Timetable of the Group session 156

5.3 Content analysis description 159

5.4 Thematic analysis description 160

5.5 Three research phases in this study. 161

5.6 Percentage frequency of ten most recurring codes for ‘meaning of energy use at home’ per archetype. 162

5.7 Percentage frequency of ten most recurring codes for ‘meaning of energy use at home’ per archetype. 162

5.8 Number one factor per archetype for the five subcategories 167

6.1 Final characteristics of the archetypes 184

List of Figures

1.1 Diagram of adapted version of theory of interpersonal behaviour (Triandis, 1977). 38

1.2 Knowledge levels and respective eliciting methods (adapted from (Bogner et al., 2009; Visser et al., 2005)). 43

1.3 Outline of thesis 47

2.1 Dutch electricity consumption and appliance breakdown and Gas consumption (adapted from Majcen, 2016; Milieucentraal, 2016) 64

2.2 Conceptual Framework: Loss of homeostasis (discomfort, distress) triggers the occupant to find again a more neutral state (i.e. comfort). This is performed by manipulating their environment (via interaction with appliances, systems) through behaviors (habits or control). Behaviors are to an extent guided by emotions and attitudes. Finally, when homeostasis is achieved, health and wellbeing are achieved in the long term. The interaction with the environment results in energy use. 71

3.1 Cluster Sizes: (respondents) Percentage. 90

3.2 Flow diagram of process from Two Step Cluster Analysis to Archetype naming. 91

4.1 Study design 120

4.2 Visual comparison of relative values of different variables per archetype. 137

5.1 Knowledge levels and respective eliciting methods (adapted from (Bogner et al., 2009; Visser et al., 2005)). 152

5.2 The floor plan of the Multisense lab: observation room and the control room (A: microphones, B: cameras, C: moderator, D: observer in one-sided mirror, E: camera controller, F: participants). 155

5.3 Seven-step analysis process. 158

5.4 Categories, sub-categories, and factors of affinity diagram. 164

5.5 Results 'Meaning of energy use at home' 165

5.6 Results 'Ideal Home Experience' 166

6.1 Ranking of Archetypes for energy use and comfort affordance needs. 182

TOC

Summary

This research is aimed at better understanding how occupants use energy in their homes from a comfort-driven perspective, in order to propose customized environmental characteristics that could improve the occupants' comfort while reducing energy consumption. To propose such bespoke environmental features and feedback, occupant archetypes were produced based on the intentions and motivations behind comfort behaviours. Building upon the aim of this thesis, the following main research question was proposed:

How can energy behaviours be studied from a comfort-driven perspective in order to facilitate the development of environmental features that support more efficient occupant behaviours and that provide the comfort needs of the person?

A mixed-methods human-centered design approach was developed for which four steps were required to answer the main research question, reflecting also the four parts of this dissertation.

1 An extensive and multidisciplinary literature review investigated behavioural theories and comfort theories to find out what the drivers behind behaviours are and to understand comfort from a holistic and integrative lens, including social and psychological comfort. Additionally, an overview of energy use in residential buildings was presented, along with the links between energy consumption and occupant behaviours, thus explaining the problems of performance gaps and the rebound effect. The review eventually proposes that energy consumption, behaviours, and comfort are elements of an interacting system, as many behavioural expressions exercised at home are comfort-driven and several of these comfort-driven behaviours result in energy use. This part was the platform on which a questionnaire was developed based on constructs that motivate behaviour: locus of control, attitudes towards energy, environmental needs, and emotions towards home, in addition to other variables such as health status, demographics, and energy consuming habitual actions. Thus, the questionnaire is a tool that consolidates in a single instrument a self-reported assessment of energy consumption patterns and comfort behaviours. The resulting questionnaire was composed of previously validated instruments that were adapted to the context to assess the corresponding constructs and was composed of 65 variables.

2 The newly developed questionnaire was pilot tested with a population consisting of master students of the faculty of Architecture and the Built Environment of the TU Delft. The pilot was launched to make corrections and adjust the questionnaire and to validate the effectiveness of the analysis method to cluster respondents. The TwoStep cluster analysis was chosen as it is a method normally used in the segmentation of health behaviours and was originally developed to group customers in marketing. More recently, it has been used in studies assessing different types of behaviours, especially in the healthcare field. The pilot ensured that the segmentation method was appropriate for the types of variables involved. The cluster analysis produced a model of six clusters, which was successfully validated according to a process that ensures that the groups are both stable and reliable.

Subsequently, the questionnaire was administered to the full sample of 761 respondents –mainly composed of students and employees- and was analysed accordingly with the method. The final model was also validated. The final model resulted in five distinct home occupant clusters, which differed on their comfort needs, attitudes towards energy, environmental control beliefs, and emotions towards their home environment. These clusters were the basis of the forthcoming archetypes.

3 In order to better develop the archetypes, occupant-related qualitative data and environment-related quantitative data was needed. A field study was designed to interview occupiers in their homes and to gather building data. To gather building data, a comprehensive checklist inventoried building characteristics related to energy expenditure, such as type of glazing, type of ventilation, type of appliances, etc. Additionally, the indoor environmental parameters (relative humidity, carbon dioxide, and temperature) were monitored, and finally, actual energy consumption readings were taken for a month during the summer period. Parallelly, in-depth and semi-structured interviews were conducted, which are techniques used to gather qualitative behavioural data from the home occupants. Questions related to their energy consuming habits and practices were asked, as well as about their environmental needs for comfort and energy attitudes. Interviews were analysed with a text mining technique: sentiment analysis, which allows assessing the sentiments associated with the topics discussed. Both qualitative and quantitative data were used to complete the previously found statistical clusters, in order to develop the five final archetypes that are the following: Archetype 1: Restrained Conventionals; Archetype 2: Incautious realists; Archetype 3: Positive savers; Archetype 4: Sensitive wasters; Archetype 5: Vulnerable pessimists.

4 Self-reported data and interviews allow collecting explicit knowledge: a type of knowledge that is readily available and is related to facts and memories. When verbally expressed, these facts and memories tend to be processed through

biases and conscious filters. As a result, to produce more accurate and complete archetypes, another type of knowledge is also needed: tacit knowledge. This is a type of knowledge is related to feelings, intuitions, and emotions, which tends to be difficult to express with verbalizations. To collect it, focus group sessions were designed to assess the home occupants' tacit knowledge in terms of what it means to use energy in their homes and what the ideal home experience is. This was collected with the generation of collages that the participants produced with visual and tactile materials, after which they described the process and meanings of their creations. The data was analysed with the use of affinity diagrams that allows to group large amounts of qualitative data into manageable categories and to see the relations between the categories. The results showed two categories: building and occupant, with five sub-categories in total: behavioural aspects, psychological aspects, energy aspects, financial aspects, and home aspects. Each of these sub-categories was composed of codes extracted from the collages produced and from the verbal explanations given by the participants. Finally, the data was related back to each of the archetypes, in order to produce final fully-fledged archetypes. The results show that each archetype has different needs, expectations, and experiences as to how they appraise energy and how they desire comfort in their own houses. Consequently, this gives insights into the fact that each of the archetypes is different, they each need differing environmental features to satisfy their comfort needs, to achieve that comfort, and to perceive the impact of their comfort behaviours on the energy outputs of their household.

The differing characteristics that each archetype exhibited were translated into preliminary customized design parameters or bespoke environmental features for each of them. They are summed up as follows: the Restrained Conventional needs large windows for a view and a connection to the outside. Because they value personal space and social interaction at home, yet have low environmental control, the plan of the home needs to give a transition from private to social. They are conservative in the energy use and concerned about their finances: energy feedback can be given to them relating their practices to monetary consequences.

The Incautious Realist places importance on having the right size and layout for particular purposes: therefore, they need modularity that they can manually control, due to their high external control. They also value safety and privacy, so the interactions with façade elements need to ensure them that their environment is safe and private. They have a high concern about finances, yet they have a high expenditure. To boost their consumption and their need for control, their home can be equipped with a control station from which they can control appliances, and see their consumption as a financial reflection.

The Positive Saver places value on the cleanliness and orderliness of the place, thus they need surfaces and spaces that are easy to clean and reach. They are the biggest savers of all the archetypes and this seems to be due to their environmental concerns. To reduce even further their consumption, feedback can be given to them by translating their comfort actions –oven use, etc. – into environmental consequences.

The Sensitive Waster needs softness and tactile sensations in their house. They also place importance on having high freedom of their practices in their house. They are the largest energy waster, and they do not worry about their finances, however, they do value the environment and the future. A smart feature can be designed for them to save more energy by equating their practices to ecological consequences to have a more conservative energy use.

The Vulnerable Pessimist places emphasis on the aesthetics of the house, the technologies, and the gadgets. They also value a sense of community and connectedness to their neighbourhood. As result, they need homes that allow for these interactions, in small complexes or pavilions. They do not worry about financial aspects, however their expenditure is middle-range: to improve it; they can receive feedback from the consumption of their community as an awareness tool.

The findings of this study can help to improve energy predictions, by making more accurate models with different types of occupants. Furthermore, for the existing housing stock, corporations can use the archetypes to tailor the indoor environmental features and interfaces to the future occupant; or, similarly, different occupants can be better allocated to better matching existing dwellings. As for the design of the future stock, architects and contractors can make use of the archetypes by having a more inclusive design process, by answering real needs of the future occupant and improving the decision making of architects. For policies and energy efficiency programs, knowing that there are different types of occupants can allow to bridge gaps between occupant and provider, by encouraging a participatory or inclusive research and design phase, for the design of devices, feedbacks, and interfaces tailored to the specific archetype.

Samenvatting

Dit onderzoek is gericht op het beter begrijpen van hoe bewoners in hun woningen energie gebruiken vanuit een comfort gedreven invalshoek, zodat op maat gemaakte omgevingseigenschappen die het comfort van de bewoner verbeteren en energie besparen kunnen worden bepaald. Voor het bepalen van dergelijke omgevingseigenschappen en terugkoppelingen, zijn bewoners archetypen gebaseerd op de intenties en motivaties onderliggend aan de comfortgedragingen gemaakt. Voortbouwend op het doel van deze dissertatie, werd de volgende hoofdonderzoeksvraag gesteld:

Hoe kan gedrag t.a.v. energie vanuit een comfort gedreven invalshoek worden bestudeerd, zodanig dat de ontwikkeling van omgevingseigenschappen die een efficiënter bewonersgedrag bewerkstelligen en de comfort behoeftes van de persoon leveren?

Om de hoofdonderzoeksvraag te beantwoorden werd een mixed-methode ontwerpbenadering ontwikkeld waarin de mens centraal staat. Deze benadering bestaat uit vier stappen weergegeven in de vier delen van deze dissertatie.

1 Vanuit een holistische en integratieve lens, zijn middels een uitgebreide en multidisciplinaire literatuurstudie gedrag en comfort theorieën in kaart gebracht om uit te zoeken wat de drijfveren zijn van bepaalde gedragingen en om comfort, inclusief sociaal en psychologisch comfort. Om de problemen van prestatieverschillen en het rebound-effect te verklaren, is samen met de relaties tussen energiegebruik en bewonersgedrag een overzicht van energiegebruik in woonhuizen gepresenteerd. Uiteindelijk wordt in de review gesteld dat energiegebruik, gedrag, en comfort, onderdelen zijn van een interactief systeem omdat veel gedragingen die thuis worden uitgevoerd comfort gedreven zijn en verscheidene van deze comfort gedreven gedragingen leiden tot energiegebruik. Dit deel vormde de basis voor de ontwikkeling van een vragenlijst die is gebaseerd op gedrag-motiverende bouwstenen: locus of control, houding t.a.v. energie, omgevingsbehoeften, en emoties t.a.v. thuis, naast andere variabelen zoals gezondheidsstatus, demografische gegevens, en gewoontes die energie gebruiken. De vragenlijst is daarom een tool die een zelf-rapporterende beoordeling van energiegebruik patronen en comfort gedrag in een enkelvoudig instrument samenvoegt. De resulterende vragenlijst bestond uit eerder

gevalideerde instrumenten die zijn aangepast op de context voor het beoordelen van de bijbehorende bouwstenen en bestaat uit 65 variabelen.

2 De nieuw ontwikkelde vragenlijst is gebruikt in een pilot met een populatie bestaande uit bachelor studenten van de faculteit Bouwkunde van de TU Delft. De pilot was bedoeld om correcties door te voeren, de vragenlijst aan te passen, en om de effectiviteit van de analyse methode voor het clusteren van respondenten te valideren. The TwoStep cluster analyse is gekozen omdat dit een methode is die normaliter wordt gebruikt bij het segmenteren van gezondheidsgedrag en omdat deze methode oorspronkelijk is ontwikkeld voor het groeperen van klanten in marketing. Meer recent is het gebruikt in studies waarbij verschillende soort gedrag werd beoordeeld, met name in de gezondheidszorg. De pilot bevestigde de geschiktheid van de segmentatie methode voor de betrokken soorten variabelen. De cluster analyse produceerde een model van zes clusters, die met succes zijn gevalideerd volgens een proces dat resulteerde in stabiele en betrouwbare groepen.

Vervolgens is de vragenlijst uitgezet bij de volledige sample van 761 respondenten –vooral studenten en medewerkers- en de uitkomst is volgens de methode geanalyseerd. Het definitieve model is ook gevalideerd. Het definitieve model resulteerde in vijf duidelijke clusters van bewoners, met verschillen in comfortbehoeften, houding t.a.v. energie, veronderstellingen t.a.v. beheersing van de omgeving, en emoties t.a.v. hun woonomgeving. Deze clusters vormen de basis van de op komst zijnde archetypen.

3 Bewoner gerelateerde kwalitatieve gegevens en omgeving gerelateerde kwantitatieve gegevens zijn nodig voor het beter ontwikkelen van de archetypen. Een veldstudie is ontworpen om bewoners in hun huis te interviewen en om gebouwgegevens te verzamelen. Middels een uitvoerige checklist zijn gebouweigenschappen gerelateerd aan energie uitgaven, zoals soort beglazing, ventilatiesysteem, installaties, etc., verzameld. Daarnaast zijn de binnenmilieu parameters (relatieve vochtigheid, kooldioxide en temperatuur) geregistreerd, en tot slot is het actuele energieverbruik gedurende een maand in de zomer afgelezen. Parallel daaraan zijn diepte en semigestructureerde interviews gehouden. Dit is een techniek die wordt gebruikt om kwalitatieve gedragsgegevens van bewoners te verzamelen. Vragen gingen over energie verbruikende gewoonten en gebruiken, maar ook over omgevingsbehoeften t.b.v. comfort en over houding t.a.v. energie. De interviews zijn geanalyseerd middels een textmining techniek: sentiment analyse, die het toestaat om sentimenten geassocieerd met de onderwerpen die ter discussie stonden te beoordelen. Zowel kwalitatieve als kwantitatieve gegevens zijn gebruikt om de eerder gevonden statistische clusters compleet te maken, hetgeen resulteerde in de vijf definitieve

archetypen: Archetype 1: Sobere Conventioneel; Archetype 2: Onbezonnen Realist; Archetype 3: Positieve Bespaarder; Archetype 4: Gevoelige Verbruiker; Archetype 5: Kwetsbare Pessimist.

4 Zelf-gerapporteerde gegevens en interviews maken het verzamelen van expliciete kennis mogelijk: een soort kennis dat direct aanwezig is en gerelateerd is aan feiten en herinneringen. Wanneer deze feiten en herinneringen mondeling worden uitgedrukt, lijken ze een proces met afwijkingen en bewuste filters te doorlopen. Voor het genereren van preciezere en completere archetypen, is daarom een ander soort kennis nodig: non-verbale kennis. Dit is een soort kennis die relateerd aan gevoelens, intuïtie, en emoties, en is meestal moeilijk uit te drukken met woorden. Om deze kennis te verzamelen, zijn er focus groep sessies ontworpen om de non-verbale kennis van bewoners in termen van wat het betekent om energie te gebruiken in hun woningen en wat de ideale woonervaring is, te bepalen. Deze kennis is verzameld middels collages die de deelnemers met visuele en non-verbale materialen maakten. Na het maken ervan beschreven zij het proces en de betekenissen van hun creaties. De gegevens zijn geanalyseerd met behulp van affiniteit diagrammen, die toestaan om grote hoeveelheden kwalitatieve gegevens te groeperen in beheersbare categorieën en om relaties tussen de categorieën zichtbaar te maken. De resultaten laten twee categorieën zien: gebouw en bewoner, met in totaal vijf subcategorieën: gedragsaspecten, psychologische aspecten, energie aspecten, financiële aspecten, en woning aspecten. Elk van deze subcategorieën is opgebouwd uit codes, die afgeleid zijn van de gemaakte collages en van de verbale verklaringen van de deelnemers. Tenslotte zijn, om de definitieve volwaardige archetypen te bewerkstelligen, de gegevens met de archetypen gerelateerd. De resultaten laten zien dat elk archetype verschillende behoeftes, verwachtingen, en ervaringen heeft, maar ook hoe zij energie waarderen en hoe zij comfort in hun eigen woning willen hebben. Dit resulteert vervolgens in het feit dat elk van de archetypen verschillend is: zij hebben verschillende omgevingseigenschappen nodig om hun comfortbehoeftes te verzorgen, om dat comfort te bereiken, en om het effect van hun comfortgedrag op het energiegebruik van hun huishouding te beseffen.

Tot slot zijn de verschillende eigenschappen die elk archetype typeert, vertaald in eerste klantgerichte ontwerp parameters of specifieke omgevingseigenschappen per groep. Deze zijn als volgt opgesomd: de Sobere Conventioneel heeft behoefte aan grote ramen met uitzicht en een relatie met buiten. Omdat zij persoonlijke ruimte en sociale interactie thuis zeer waarderen, maar toch een lage omgevingsbeheersing hebben, zal de plattegrond van de woning een transitie van privaat naar sociaal moeten laten zien. Ze zijn conservatief in het gebruik van energie en bezorgd om financiën: energieterugkoppeling kan aan hen worden gegeven zodat hun acties worden gerelateerd aan financiële gevolgen.

De Onbezonnen Realist vindt de juiste afmetingen en indeling voor bepaalde doelen belangrijk: vanwege hoge externe beheersing hebben zij handmatige beheersbare modulariteit nodig. Ook waarderen zij veiligheid en privacy. Interacties met gevelelementen zijn belangrijk zodat zij verzekerd zijn dat de omgeving veilig en privaat is. Zij hebben veel zorgen over geld, toch besteden zij veel. Om hun besef van gebruik en behoefte aan controle te verhogen, zou in hun woning een controlestation kunnen worden geïnstalleerd waarmee zij hun energiegebruik en kosten kunnen inzien.

De Positieve Bespaarder waardeert hygiëne en netheid van de woning, dus zij hebben oppervlakken en ruimten nodig die makkelijk schoon te maken en bereikbaar zijn. Zij zijn de grootste Bespaarders onder alle archetypen en dit lijkt veroorzaakt te worden door hun zorgen voor de omgeving. Om hun energiegebruik nog meer te reduceren, zou terugkoppeling kunnen worden gegeven over het effect van hun comfort acties –ovengebruik, etc. – op de omgeving.

De Gevoelige Verbruiker heeft zachtheid en non-verbale sensaties in de woning nodig. Zij vinden ook het vrij zijn in hun doen en laten in de woning belangrijk. Zij gebruiken de meeste energie, en maken zich geen zorgen over geld, maar waarderen de omgeving en de toekomst zeer. Een slim instrument kan worden ontworpen die hun activiteiten met de ecologische gevolgen vergelijkt, waardoor ze meer energie kunnen besparen en tot een conservatiever energiegebruik leidt.

De Kwetsbare Pessimist legt de nadruk op de esthetica van de woning, technologie en gadgets. Zij waarderen ook het gemeenschapsgevoel en connectiviteit met hun buurt. Daarom hebben zij woningen nodig die deze interacties toelaten, in een klein complex of paviljoen. Zij maken zich geen zorgen over financiële aspecten, al zijn hun uitgaven gemiddeld: om dit te verbeteren, kunnen zij terugkoppeling krijgen over het verbruik van de gemeenschap als een bewustwordingsinstrument.

De uitkomsten van de archetypes kunnen via het creëren van nauwkeurigere modellen met verschillende bewoner types, helpen bij het verbeteren van energie voorspellingen. Daarnaast kunnen de archetypes worden gebruikt door bedrijven om de binnenmilieu aspecten en interfaces van de bestaande woningvoorraad voor de toekomstige bewoner op maat te maken; of, soortgelijk, verschillende bewoners kunnen beter aan passende bestaande gebouwen worden toegewezen. Ten aanzien van de toekomstige voorraad, kunnen architecten en aannemers door gebruik te maken van de archetypes middels een meer inclusief ontwerpproces, voldoen aan de echte eisen van de toekomstige bewoner en daarmee het besluitproces van de architecten verbeteren. Voor beleidslijnen en energie-efficiëntie programma's kan de kennis dat er verschillende typen bewoners bestaan, via het stimuleren van

participatief onderzoek en ontwerpfase, met op maat ontworpen instrumenten, terugkoppelingen, en interfaces per archetype, het gat tussen de bewoner en de leverancier overbruggen.

TOC

TOC

Sommaire

Cette étude vise à mieux comprendre comment les occupants utilisent l'énergie chez eux à partir du point de vue du confort pour ainsi proposer des environnements personnalisés ou des produits individualisés qui auraient pour but d'améliorer le confort des habitants tout en garantissant des économies d'énergie. Pour proposer ce type de produits ou d'environnements, des archétypes d'occupants ont été développés selon les intentions et les motivations derrière leurs habitudes vis-à-vis du confort. C'est à partir de ce constat que la question principale de cette thèse surgit :

Comment pouvons-nous étudier les comportements énergétiques des occupants des maisons, à partir d'un point de vue du confort, pour rendre possible le développement de produits ou des environnements qui en plus d'apporter du confort nécessaire aux habitants, puissent accueillir des comportements plus efficaces vis-à-vis de l'énergie ?

Cette étude a utilisé deux approches : des « méthodes mixtes » et de la conception centrée sur l'humain. Au moyen de chacun des approches nous avons essayé de répondre à la question principale de cette thèse à l'aide de quatre étapes. Ces étapes correspondent ainsi aux quatre chapitres de ce mémoire.

1 Une analyse documentaire vaste et pluridisciplinaire a établi les différents types de théories du comportement pour mieux comprendre quels sont les facteurs contribuant aux conduites humaines et pour définir une vue plus globale du concept de « confort ». En plus, une vue d'ensemble a été présentée à propos de la consommation d'énergie et sa corrélation avec les comportements des occupants de maisons, en expliquant des problèmes divers comme les écarts de performance énergétique ou le phénomène du « rebond ». L'analyse propose ainsi que la consommation d'énergie, les comportements et le confort sont des éléments qui interagissent entre eux et qui font partie d'un seul système. Cela est dû au fait que beaucoup de comportements que les occupants pratiquent chez eux sont motivés par l'envie de confort et à leur tour consomment de l'énergie.

Cette première partie est la base sur laquelle une enquête a été développée qui vise à évaluer les modèles psychologiques qui motivent les comportements : le locus de contrôle, les attitudes à l'égard de l'énergie, les besoins environnementaux et les

émotions autour de l'environnement résidentiel. D'autres données qui font partie de l'enquête sont : l'état de santé de l'habitant, des données démographiques et des habitudes qui consomment de l'énergie. Cette enquête est donc un moyen de regrouper sous un même instrument d'auto-évaluation des outils pour mesurer les modèles et schémas de consommation énergétique et des comportements face au confort. Le questionnaire définitif se compose de 65 variables issues d'autres instruments précédemment validés et qui ont été adaptées au contexte de cette thèse.

2 La nouvelle enquête a été testée dans le cadre d'un projet pilote avec une population cible composée d'étudiants de master de la faculté d'Architecture et de l'Environnement Bâti de la TU Delft. L'essai pilote a été lancé pour faire des corrections et des ajustements à l'enquête et pour valider l'efficacité de la méthode analytique pour former des « grappes statistiques » de répondants selon leurs réponses. Une analyse typologique appelée « TwoStep » a été adoptée. Cette analyse est normalement utilisée dans la segmentation des comportements liés à la santé même si à l'origine elle a été développée pour trouver des catégories de consommateurs en marketing. Plus récemment cette méthode a été employée pour évaluer les différents types de conduites des groupes étudiés, spécialement dans le domaine de la santé. L'essai pilote a garanti que la méthode de segmentation était appropriée pour les types de variables utilisées dans le questionnaire. L'analyse topologique de l'essai pilote a produit un modèle de six grappes qui a été dûment validé selon un processus qui garantit la stabilité et fiabilité des groupes. Postérieurement l'enquête a été employée auprès de la population cible totale : composée de 761 répondants, constituées principalement d'étudiant(e)s et d'employé(e)s. Les données ont été analysées selon la méthode qui avait été testée précédemment. Les résultats du questionnaire et de l'analyse ont produit un modèle de cinq grappes bien distinctes d'occupants de maisons qui différaient sur les points suivants : le besoin de confort, l'attitude à l'égard de la consommation d'énergie, les croyances à propos du contrôle sur l'environnement et les émotions qui entourent le milieu de vie. Ces grappes statistiques ont été décisives dans la formation de la base des archétypes d'occupants de maisons en devenir.

3 Pour développer les archétypes des données qualitatives et quantitatives des habitants et de leurs immeubles ont dû être recueillies. Pour ce faire une étude de terrain a été créée et composée de plusieurs parties. Tout d'abord il a été question de mener des entretiens personnels avec les participants pour remplir une liste de vérification de caractéristiques des immeubles. La liste a été formulée en sorte de créer un inventaire de toutes les particularités du bâtiment liées à la consommation énergétique : tels que le type de vitrage, la ventilation, les matériaux de construction, mais aussi la quantité d'appareils électriques, etc. Par la même occasion des

paramètres de l'environnement intérieur (humidité relative, dioxyde de carbone et température) ont été suivis. Finalement des enregistrements de la consommation d'énergie réelle ont été relevés. En parallèle des entretiens semi-structurés et en-profondeur ont été conduits de façon à recueillir des données qualitatives des comportements des participants. Les questions posées étaient associées aux habitudes et aux activités qui consomment de l'énergie, au besoin de confort, et aux attitudes envers l'énergie. Les entretiens ont été analysés avec une technique d'extraction de données du texte, c'est à dire l'analyse des sentiments. Cette technique permet d'évaluer les sentiments associés aux thèmes abordés pendant l'entretien. Finalement les données qualitatives et quantitatives ont été utilisées pour compléter les grappes statistiques qui ont été trouvées précédemment par le biais de l'enquête. C'est ainsi que nous avons pu développer les archétypes définitifs: archétype 1 : les conventionnels modérés ; archétype 2 : les réalistes imprudents ; archétype 3 : les épargneurs positifs ; archétype 4 : les gaspilleurs sensibles et archétype 5 : les pessimistes vulnérables.

4 Les données auto-déclarées de l'enquête et celles des entretiens reflètent les connaissances explicites. Elles sont d'accès facile car elles impliquent le savoir des faits et des mémoires. Lorsqu'ils sont exprimés verbalement, ces faits et mémoires sont généralement filtrés à travers des préjugés ou des triages conscients. Par conséquent pour produire des archétypes plus complets et précis, une autre sorte de connaissances sont nécessaires : les connaissances tacites. Ce genre de savoir est lié aux impressions, les intuitions et les émotions qui sont généralement plus difficiles à accéder et exprimer verbalement. C'est pourquoi des séances de groupes de discussion ont été conduites pour accéder aux connaissances tacites des participants ainsi que pour mieux comprendre le sens que les participants donnent à « l'utilisation de l'énergie chez eux » et à « l'expérience de l'habitation idéale ». Pour exprimer ces connaissances les participants ont fait des collages à l'aide de matériaux simples et tactiles. Suite à l'activité de création les participants ont présenté leurs travaux. À la fin de cette présentation, les collages ont été analysés pour extraire les données brutes et les classer à l'aide d'un diagramme d'affinité. Ce dernier permet de regrouper grandes quantités d'informations recueillies pendant la séance et de les subdiviser en catégories plus faciles à gérer qui permettent aussi de trouver des liens entre elles. Deux classes principales ont été découvertes : celles du bâtiment et celles de l'occupant. Elles sont composées de cinq sous-catégories : aspects comportementaux, aspects psychologiques, aspects énergétiques, aspects financiers et aspects résidentiels. Chacune de ces sous-catégories se compose de codes extraits des collages et des descriptions exprimées par les participants. Finalement ces informations ont été associées aux archétypes pour les complémenter et créer les archétypes définitifs.

Les résultats montrent que chaque archétype a des besoins divers, des attentes et d'espoirs différentes concernant leur façon de juger et d'évaluer le concept d'énergie ainsi que des souhaits et désirs multiples de confort dans la maison. Ceci donne un aperçu de chaque archétype et montre que les personnes concernées ont besoin de différentes caractéristiques environnementales chez eux pour satisfaire leurs besoins de confort, pour atteindre leur confort personnel et pour percevoir l'impact de leurs comportements sur la consommation d'énergie domestique.

Les particularités divergentes que chaque archétype a présenté ont été traduites par de paramètres de conception préliminaires adaptés aux attributs environnementaux personnalisés pour chaque archétype. Ces particularités peuvent être résumées de la manière suivante : les « conventionnels modérés » ont besoin de grandes fenêtres et d'une connexion avec l'extérieur. Ceci est dû au fait qu'ils apprécient l'espace personnel et au même temps les interactions sociales chez eux, mais ils ont un faible contrôle environnemental. Le plan d'étage de leur bâtiment doit leur offrir une transition naturelle du privé au social. Ils sont conscients du gaspillage d'énergie et ils sont préoccupés par l'aspect financier de celui-ci. Dans ce cas il pourrait être donné des conseils leur avertissant l'impact sur le plan financier de leurs habitudes énergétiques.

Les « Réalistes Imprudents » accordent de l'importance aux dimensions et à la conception de l'espace ; ils ont besoin de lieux spécifiques pour des actions diverses. C'est-à-dire qu'ils requièrent un plan modulaire avec la possibilité d'un réglage manuel en raison de leur envie élevée de contrôle de l'environnement. Ils apprécient particulièrement la sécurité et le respect de l'intimité. Ils s'inquiètent de leur économie mais ce sont des grands consommateurs d'énergie. Pour les stimuler à faire une réduction de leurs dépenses énergétiques et au même temps satisfaire ce besoin de maîtrise de l'environnement, leur immeuble peut être équipé d'un poste de contrôle. À partir de ce poste ils pourraient avoir la commande des appareils électriques, des lumières, etc. et simultanément observer leur consommation en termes d'argent.

Les « Epargneurs Positifs » trouvent le confort dans un environnement propre et ordonné, ils ont donc besoin de surfaces qui soient faciles à nettoyer et très accessibles. Ils représentent l'archétype qui gaspille le moins d'énergie, ce qui semble s'expliquer par leur intérêt aux questions environnementales. Pour réduire davantage leur consommation, ils pourraient être informés des conséquences sur l'environnement lorsqu'ils utilisent l'énergie pour des activités liées confort (utilisation du four, etc.).

Les « Gaspilleurs Sensibles » ont besoin d'un environnement douillet et avec des sensations tactiles. Ils accordent une grande importance à la liberté d'action et de choix. En même temps ce sont les plus gros gaspilleurs énergétiques et ils ne se préoccupent pas aux conséquences financières de leurs actions. En revanche ils valorisent l'environnement et l'avenir. L'immeuble habité par cet archétype pourrait donc être équipé d'une fonction intelligente pour aider à réduire drastiquement les dépenses énergétiques et pour montrer aux occupants comment leurs actions et choix peuvent contribuer aussi à prendre soin de la planète.

Les « Pessimistes Vulnérables » apprécient l'aspect esthétique de leurs maisons et il s'agit généralement de « technophiles ». Ils aiment bien le sentiment d'identité et d'appartenance à une communauté. Par conséquent ils ont besoin d'une maison qui leur permette ce type d'interaction : par exemple les ensembles pavillonnaires c'est un milieu qui leur correspond. Les aspects financiers de la consommation ne sont pas un souci pour eux et leurs dépenses énergétiques se trouvent dans la moyenne. Pour les aider à réduire cette consommation en tant qu'outil de sensibilisation, il pourrait être mis en place un système de « retours comparatifs » des dépenses énergétiques du réseau des ménages du complexe.

Les résultats de cette étude peuvent aider à améliorer les prévisions énergétiques en créant des modèles et des simulations plus précises pour les différents types d'occupants. En prime pour le parc immobilier actuel, les organismes bailleurs peuvent utiliser les archétypes pour adapter les interfaces et les caractéristiques de l'environnement intérieur pour les futurs occupants. De la même manière les différents profils d'habitants peuvent être analysés et répartis dans les logements plus en accord avec leurs caractéristiques et celles des immeubles existants.
En ce qui concerne la conception des logements du futur, les architectes et les entrepreneurs du secteur du bâtiment peuvent utiliser les archétypes pour adopter un processus de conception plus inclusif. Ceci peut permettre de répondre aux besoins réels du futur occupant et améliorer les prises de décision des architectes. Avoir conscience qu'ils existent différents types d'occupants va permettre de faire le lien entre l'utilisateur et le fournisseur d'énergie dans le but de développer des politiques et des programmes en matière d'efficacité énergétique. De ce fait il pourrait être encouragée une phase de recherche et de développement plus participative ou inclusive pour la conception de dispositifs, de rétroactions et d'interfaces adaptées aux besoins spécifiques de chaque archétype.


Brandweer Beekbergen
System's Energy Levels
High
Low
Any energy level above the ground state is possible
Ground state

TOC

1 Introduction

1.1 Background and problem definition

Problem definition

People spend about 60% of their time in their homes: environments in which the person should feel comfortable and be healthy on account of the technical services and systems in their building (Jia, Srinivasan, & Raheem, 2017). The supply of a comfortable environment should be achieved in an energy efficient way, especially if we are to achieve the EU 2020 or 2030 targets of residential energy consumption. However, in spite of the technological advancements and energy efficient technologies that have already been developed to provide comfort, energy consumption is not decreasing at the rate it should (Tsemekidi Tzeiranaki et al., 2019). There are several complex factors affecting energy consumption of which occupant behaviours is one of them, and building systems, services, and products being some of the others. Moreover, the indoor environmental quality (IEQ) field seems to focus mainly on the thermal and other physiological aspects of comfort and energy expenditure. Yet, collaboration of the IEQ field with the fields of energy engineering and social sciences to combine knowledge to have a better grasp of both sides –building and occupant- of the issue of consumption, does not seem to occur (D'Oca, Hong, & Langevin, 2018; Sovacool, 2014). Therefore, the problem that energy savings have not been achieved with the currently available technological developments could be related to the behavioural factors influencing energy consumption.

TOC

Behavioural impact on energy use

Energy consumption in houses is partly the result of the way in which the occupants behave and interact with their comfort-providing technologies and their interfaces. This is because several of the behaviours exercised at home are done to achieve comfort, and many of them spend energy: either by using gas or electricity. It is estimated that occupant behaviours influence the final energy consumption of homes by factors of between 3 to 10 (D'Oca et al., 2018; Hong, Taylor-Lange, D'Oca, Yan, & Corgnati, 2016). Other behavioural factors that have an impact on the final energy use of the house are the characteristics of the occupants and of the household, lifestyles, schedules, socioeconomic status, or culture. Some of the unintended consequences of not studying behaviours when developing comfort-providing, energy-consuming technologies are phenomena such as the rebound effect, hacking of the technologies, rejection, or misuse, all tending to lead to higher-than-expected energy consumption (Scott, Bakker, & Quist, 2012). Other problems of neglecting the human factors in energy engineering result in performance gaps: the difference between actual and theoretical energy consumption; created by the occupant lifestyle and behaviours: variables that are not taken into account when calculating energy performance of a residence. Actual energy consumption is obtained from the final energy bills of a household, taking into account every behavioural pattern and appliance utilized by the householder. Theoretical consumption is the projected consumption of a household, by only taking into account lighting, heating, hot water, but excluding potential appliances that the occupants will use. Appliances represent an average of 32% of the final household energy consumption (Majcen, 2016; D Majcen, LCM Itard, & H Visscher, 2013; Milieucentraal, 2016).

Occupants carry out in their homes a wide variety of activities that result in energy expenditure. Many of which are performed to achieve comfort -beyond a thermal comfort or other physiological type of comfort. Several of these comfort-driven behaviours are also guided by the lifestyle of the occupant, their culture, their background, and their mental models and worldviews.

Behavioural Theories

Consequently, such behaviours need to be investigated and understood in depth, and to do so, it is necessary to study the factors lying behind and influencing behaviour both internally and externally. Internal factors are related to the psychology of the individual and external ones are environmental factors (positive or negative stressors or stimuli) to which the individual reacts and interacts with (Bluyssen, 2014b). To study behaviours, their motivations and influencing factors, behavioural theories are used.

Fields in the social sciences have different theories to study "energy behaviours". It has to be noted that social sciences do not seek to predict behaviours: their purpose is to observe and describe tendencies. The reason for a focus on tendencies, rather than on predictions, is that humans, their behaviours, and contexts, are all factors that vary greatly for predictions to be made. Behavioural theories exist with four main lenses: economics, psychological, sociological, and educational.

Each of the theories offers tools to observe the phenomenon of 'energy consumption', and each theory describes the phenomenon under different aspects of the behaviours. The four theories can be divided into two main schools of thought: those that have a focus on the 'Individual' as the energy user and those with a focus on the 'Practices' themselves. In the first case, the individual is someone who takes choices in a rational or irrational way, and his or her behaviours are the result of several factors, conscious or unconscious as well as some external variables. Psychology and economy theories are usually from the 'Individual' school of thought. The other school of thought puts the emphasis on the practices and context around which the individual and behaviours occur. This is the case with sociological and educational theories, in which variables such as communities, social norms, family, energy supply companies, etc. also take a role in the final behaviours (Chatterton, 2011).

Social practice approaches have been carried out for several years by researchers, such as Schatzki (1996), Shove (2014), and Strengers (2014). In such approach, practices that people perform are studied and understood across space and time, and the research in the field aims at studying patterns of group behaviours. In those studies, practices are defined as the results of shared social meanings (of brands, companies, suppliers, appliances) and social norms. Furthermore, 'energy use' is defined as the result of achieving such social practices. Ultimately, social practice theory aims at understanding trends and patterns of not only energy demand, but also provision, and supply, in order to explain how they change, develop and interact across space and time.

Theory of Interpersonal Behaviour

The core of the methodology of this thesis (see section 1.4) is a human-centered design approach. Additionally, in this project, comfort is assumed as a personal perception, and energy use is assumed as the result of exercising behaviours to achieve comfort. Because of the human-centered nature of this thesis, an individualist model of behaviour was selected to study energy behaviours and comfort, in addition to the fact that in this project the mental processes behind energy-consuming comfort-driven behaviours are the main study element.

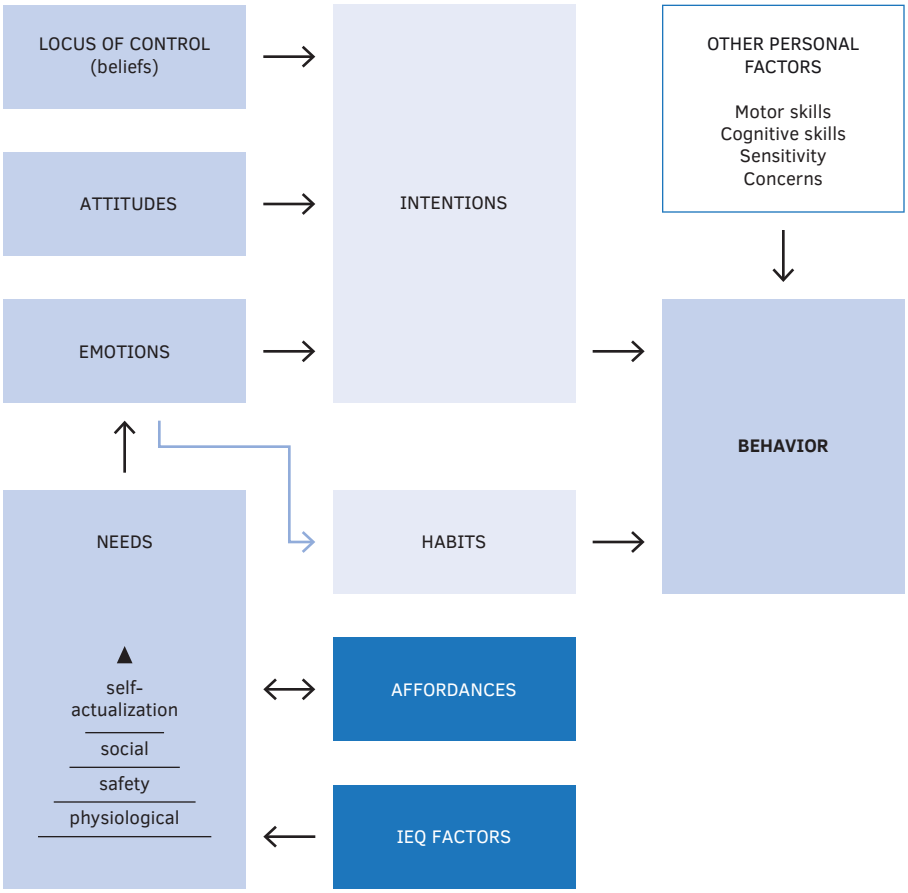


FIG. 1.1 Diagram of adapted version of theory of interpersonal behaviour (Triandis, 1977).

The approach used in this thesis, is an adapted version of the Theory of Interpersonal Behaviour (TIB) by Triandis; it observes behaviours as exercised by a specific actor –in this case the home occupant- in a rational or semi-rational process (Triandis, 1977, 1980, 1989, 2018). This model has been successfully and widely applied amongst several fields especially related to sustainability and energy (i.e. health behaviours, technology adoption, dietary behaviours, sustainable product use), which is not the case with other individual models. Another reason for using it is that when compared to other individual behavioural models, TIB is more comprehensive and includes many of the factors used in other models to study energy behaviours (Jackson, 2005; Martiskainen, 2007; Sung, Cooper, & Kettley, 2019) Finally, the individualist model is more adequate to use in this project, as opposed to a social model, as the mental processes of energy-consuming comfort driven behaviours of the home occupants are the main focus.

The core of the model contends that there are several elements motivating and influencing behaviour. Figure 1.1 shows an adapted version of the TIB model. The TIB, in brown, shows the elements that guide behaviours: beliefs (in this case locus of controls), attitudes, emotions, and need. Habits are not part of intentions, and hence are special types of behaviours. The elements in purple are environmental elements. Affordances are environmental features that allow needs to be satisfied; while IEQ factors are stimuli only perceived physiologically but processed and interpreted by the brain.

Attitudes can be conscious (cognitive) and unconscious (affective). Affective attitudes refer to a person's feelings in response to an object, situation, or concept –in the domain of this thesis, to energy and energy use. Cognitive attitudes are the conscious beliefs about energy. Attitudes act as drivers that pull the person to act in certain ways. In the thesis, the questions for the attitude section of the questionnaire were developed from the guidelines as proposed by Ajzen (2006), for which six items related to energy and energy consumption were selected and paired with five-point scale semantic differentials. The use of these guidelines has been validated in a variety of fields to measure attitudes.

Locus of control is also referred to as "control beliefs"; they are the degree to which a person believes they can influence their environment. The locus of control scale by Levenson (1981) was used since it is the best established questionnaire for measuring an individual's locus of control, having been used in several fields. For this project, the scale was adapted for the domain of the home environment by using questions about concepts of the immediate residential environment. The formulation of these items was based on the "Internal Control" and "External Control" dimensions of the original instrument, with nine items per dimension.

In this work, the terms affordances and needs go hand in hand. A need is what an individual finds necessary to be satisfied, while an affordance is the object that allows that need to be satisfied. In other words, affordances are elements that the environment provides so that a person can perform an action to satisfy a need. In the questionnaire, questions were developed by selecting items from the housing literature, that relate to psychosocial and physiological comfort. These were rated on a 5-point scale in which a high rating indicated high importance of the item to be an affordance for comfort.

Emotions are constantly guiding an individual's behaviour. Emotions are affective reactions to an environmental stimulus. These reactions occur at psychological and physiological levels. Emotions are a driver of human behaviour, health, and comfort, since emotional, behavioural, and cognitive processes interact with the nervous and

immune systems (Ortony, Norman, & Revelle, 2012). Several tools exist to assess emotions. Here, an adapted version of PrEmo2 by Laurans and Desmet (2012) was used, as it is one of the few instruments using non-verbal scales.

Finally, the TIB and several other behavioural theories contend that habits are an important element of behaviour; however, they have to be treated differently to 'normal' behaviour. Habits are different to the rest of behaviours because they are semi-unconscious, repetitive, goal oriented, and are triggered by environmental stimuli (Wood & Rünger, 2016). Because they bring a reward after execution, they play an important role to relieve stress. In this study's questionnaire, an adapted version of the Self-Report Habit Index by Maréchal (2010) was used; an instrument validated in previous questionnaires for people's habits in relation to energy use.

1.2 Aim of the study

The aim of this thesis is to better understand energy use of home occupants from a comfort-driven perspective by proposing an innovative way to research it. This is done by taking a human-centered design approach to the challenge of energy consumption and comfort.

1.3 Research questions

Following from the aim of this study the main research question emerges.

Main Question

How can energy behaviours be studied from a comfort-driven perspective in order to facilitate the development of environmental features that support more efficient occupant behaviours and that provide the comfort needs of the person?

The main question is deconstructed into each of the following key questions, which are answered in different chapters of this dissertation.

Key Questions

Part 1: Literature Review and development of Questionnaire (Chapter 2)

1 What lies behind behaviour?
2 What characterizes habits?
3 What is comfort?
4 How do home occupants achieve comfort?
5 How are comfort behaviours and energy use related in homes?

This chapter deals with the background of this dissertation. It presents a review performed to understand the steps, concepts, and variables needed to identify home energy use and its relation to comfort behaviours. Comfort is presented from different fields, from a biological perspective to emotional, behavioural, and physiological ones. The relationships between comfort, health, and wellbeing are also presented. Further on, focus is given to the energy use in buildings, and it is proposed how the energy use is related to behaviours and ultimately comfort. It is concluded that comfort is a psycho-behavioural reaction to environmental stimuli. The results of this literature review served as the stepping-stone for the development of the questionnaire (Ortiz, Kurvers and Bluyssen, 2017).

Part 2: Validation of Questionnaire, Analysis, and Development of Clusters (Chapter 3)

6 Can home occupants be grouped based on their behavioural motivations?

This chapter describes the administration of the newly developed questionnaire designed to study comfort behaviour and the selection of a good method to cluster respondents. A pilot study was performed on a sample of students from the faculty of Architecture and the Built Environment of the TU Delft. With the use of the TwoStep cluster analysis, clusters were created based on the variables of the questionnaire. With this sample, six preliminary archetypes were found. It was concluded that the developed questionnaire and the analysis method -the TwoStep cluster analysis- were an adequate method and tool to identify clusters of comfort-driven, energy-consuming patterns. However, to validate and fine tune the clusters, qualitative data from the occupants (interviews about habits, actions, needs, motivations) needed to collected and incorporated to the clusters as well (Ortiz and Bluyssen 2018). The results of this proof-of-concept gave the green light to administer the questionnaire to the full sample, from which five final clusters were produced and were the subject of study in the subsequent parts.

Part 3: Enhancement of clusters with Interview data and building features data (Chapter 4)

7 How does the indoor environment of occupant archetypes differ?
8 How do the characteristics of their buildings differ?
9 How do the different archetypes differ in their daily use of energy?
10 How do the different archetypes express comfort habits, energy, and affordances in their homes?

This chapter shows the development of the final archetypes, by administering the questionnaire to 761 respondents, and by substantiating the TwoStep cluster analysis results with those of a field study, in which interviews, IEQ monitoring, energy readings, and building checklist data were taken. Five clusters were found with the statistical analysis. The field study was performed with 15 participants, who volunteered to be interviewed and to have their dwellings monitored. The results identified that home characteristics and the indoor environment did not seem to determine the archetypes. However, energy consumption varied greatly among archetype, albeit, the sample was too small to conclude statistically significant differences. Furthermore, the analysis of the interviews suggested that each of the archetypes expresses different sentiments about their opinions on comfort habits, energy use, and environmental affordances (Ortiz and Bluyssen 2019).

Part 4: Development of the Final Archetypes (Chatper 5)

11 How do the archetypes differ in their "home comfort experience"?
12 How do the archetypes perceive their own "experience of using energy in their homes"?

In this chapter, the enhanced archetypes are further complemented with the data from focus groups. In the focus groups, representatives of each of the archetypes were invited to produce, with generative techniques, artefacts that express their mental models in terms of the meaning of using energy in their homes, and what they regard as being an ideal home experience. It was concluded that indeed, each type of occupant processes their past experiences of energy consumption differently from each other, with some being more concerned in personal, financial, or environmental factors. Likewise, each of the archetypes has different desires, wishes, needs, and expectations as to what an ideal home experience should be (Ortiz, Kim, Bluyssen 2019).

1.4 Methodology

The methodology of this research is a mixed-methods procedure and is divided into four parts, as shown below. The core of the methodology is grounded on a human-centered design approach aiming at studying phenomena by keeping people's lives and desires at the core, allowing achieving innovative solutions. In other words, human-centered design is a creative problem-solving process with a starting point from the people one designs for and with an end point of new solutions that are custom-made to satisfy their needs (IDEO.org, 2015).

The choice of methods is intended to delve into different types of occupant knowledge, which ranges from procedural knowledge (conscious) to interpretive knowledge (unconscious) (Bogner et al., 2009). Thus, as depicted in Figure 1.2 below, different methods exist to collect data from different levels of consciousness. The advantage of such techniques is that deep-lying needs and values are elicited, rather than only what people think they need (Visser et al., 2005).

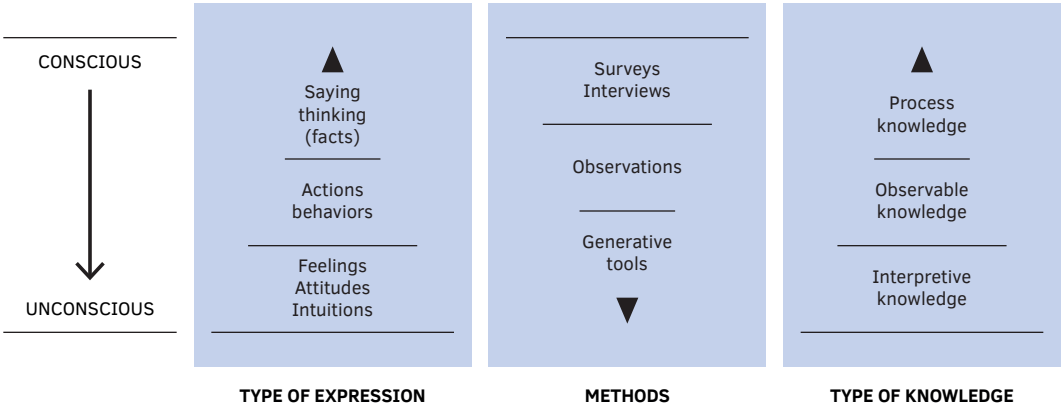


FIG. 1.2 Knowledge levels and respective eliciting methods (adapted from (Bogner et al., 2009; Visser et al., 2005)).

TOC

Part 1

The first part of the research involves carrying out a state-of-the-art review, with the most current research on the topics of comfort, from a multidisciplinary perspective, as well as behavioural theories, and energy consumption and behaviours at home. From its outcomes, the questionnaire was developed (see Appendix A) as key factors were identified to assess to understand comfort and energy behaviours.

Publications:

- Ortiz Sanchez, M., Kurvers, S., & Bluyssen, P. M. (2016). Energy consumption and comfort in homes. In P. K. Heiselberg (Ed.), CLIMA 2016: proceedings of the 12th REHVA World Congress (Vol. 6, pp. 1-11). [765] Aalborg: Aalborg University.
- Ortiz Sanchez, M., Kurvers, S. R., & Bluyssen, P. M. (2017). A review of comfort, health, and energy use: Understanding daily energy use and wellbeing for the development of a new approach to study comfort. Energy and Buildings, 152, 323-335. https://doi.org/10.1016/j.enbuild.2017.07.060

Part 2

The second phase is the development of the questionnaire, pilot testing it, and administering it. Additionally, several possible analysis approaches were researched, and the TwoStep cluster analysis was selected as the most adequate one, based on the type of variables. This was published as a proof-of-concept. Following the proof-of-concept step, the questionnaire was administered to the rest of the population and analysed in its entirety. The final Cluster model was produced, in which the outcome was five clusters.

Publications

- Ortiz Sanchez, M., Kurvers, S., & Bluyssen, P. M. (2017). Introduction to a questionnaire for occupant energy and wellbeing behaviours in homes. In Proceedings of the international scientific conference Healthy Buildings 2017-Europe [0021]
- Ortiz Sanchez, M., & Bluyssen, P. M. (2018). Proof-of-concept of a questionnaire to understand occupants' comfort and energy behaviours: First results on home occupant archetypes. Building and Environment, 134, 47-58. https://doi.org/10.1016/j.buildenv.2018.02.030

Part 3

Phase 3 involved a trial workshop to assess habits and a mixed-methods field study. For the workshop, with a special methodology, students were asked to think of comfort-driven energy-consuming habits. For the field study, representatives from each of the clusters from the previous phase were asked to be interviewed and to have their IEQ at home monitored. Fifteen interviews were conducted, IEQ measurements were taken, and their actual energy readings were recorded for one month in the summer. Interviews were analysed with sentiment analysis and the descriptive statistics were done for the quantitiave data. These were used to complete and substantiate the clusters and produce the behavioural profiles.

Publications

- Ortiz Sanchez, M., & Bluyssen, P. M. (2018). Qualitative classification of energy consuming habits of young home occupants. Abstract from Behave 2018: 5th European Conference on Behaviour and Energy Efficiency, Zurich, Switzerland.
- Ortiz Sanchez, M., & Bluyssen P. M. (2019). “Developing home occupant archetypes: first results of mixed- methods study to understand occupant comfort behaviours and energy use in homes”. Building and Environment, 163, 106331. https://doi.org/10.1016/j.buildenv.2019.106331.

Part 4

Seventeen participants representing each of the five Archetypes were invited to take part in focus group sessions. The focus groups were conducted to gain deeper understanding on the tacit knowledge of each of the profiles about energy use at home and their comfort ideals. This data was analysed qualitatively with affinity diagrams and used to have a complete picture of the Archetypes.

Publications

- Ortiz Sanchez, M., & Bluyssen P. M. (2019). “Substantiation of Home Occupant Archetypes with Generative Techniques: Analysis and Results of Focus Groups”. Building Research & Information, submitted.

1.5 Outline of thesis

As shown in Figure 1.3, in addition to the introduction and the conclusion, this dissertation has four parts to it:

Part 1, Literature Review and development of Questionnaire, has its basis on the literature review which culminates in a proposition to a new perspective of comfort and energy behaviours (Chapter 2). This literature review results in the development of the questionnaire.

Part 2, Administration and validation of Questionnaire, development of Clusters, validates the questionnaire as an appropriate instrument for the topic, and demonstrates that the clustering method is suitable for the analysis (Chapter 3).

In Part 3, Enhancement of clusters with Interview data and building features data, the full dataset with 761 respondents was analysed with the TwoStep cluster analysis, resulting in the five final clusters. Then, a field study was carried out with representatives of each cluster in which they were interviewed and their homes were monitored. The results of the field study served as the enhancement of the clusters to develop the archetypes (Chapter 4).

Part 4, Complementing the archetypes with qualitative data from focus groups, shows the results of the presentation of the final archetypes, with them being complemented with the data generated in the focus groups (Chapter 5).

Finally, Chapter 6 shows the conclusions and recommendations of the entire work, by answering the key questions and the main questions, and providing a final detailed description of the archetypes as well as the environmental features that they need to improve their comfort while reducing their energy consumption.

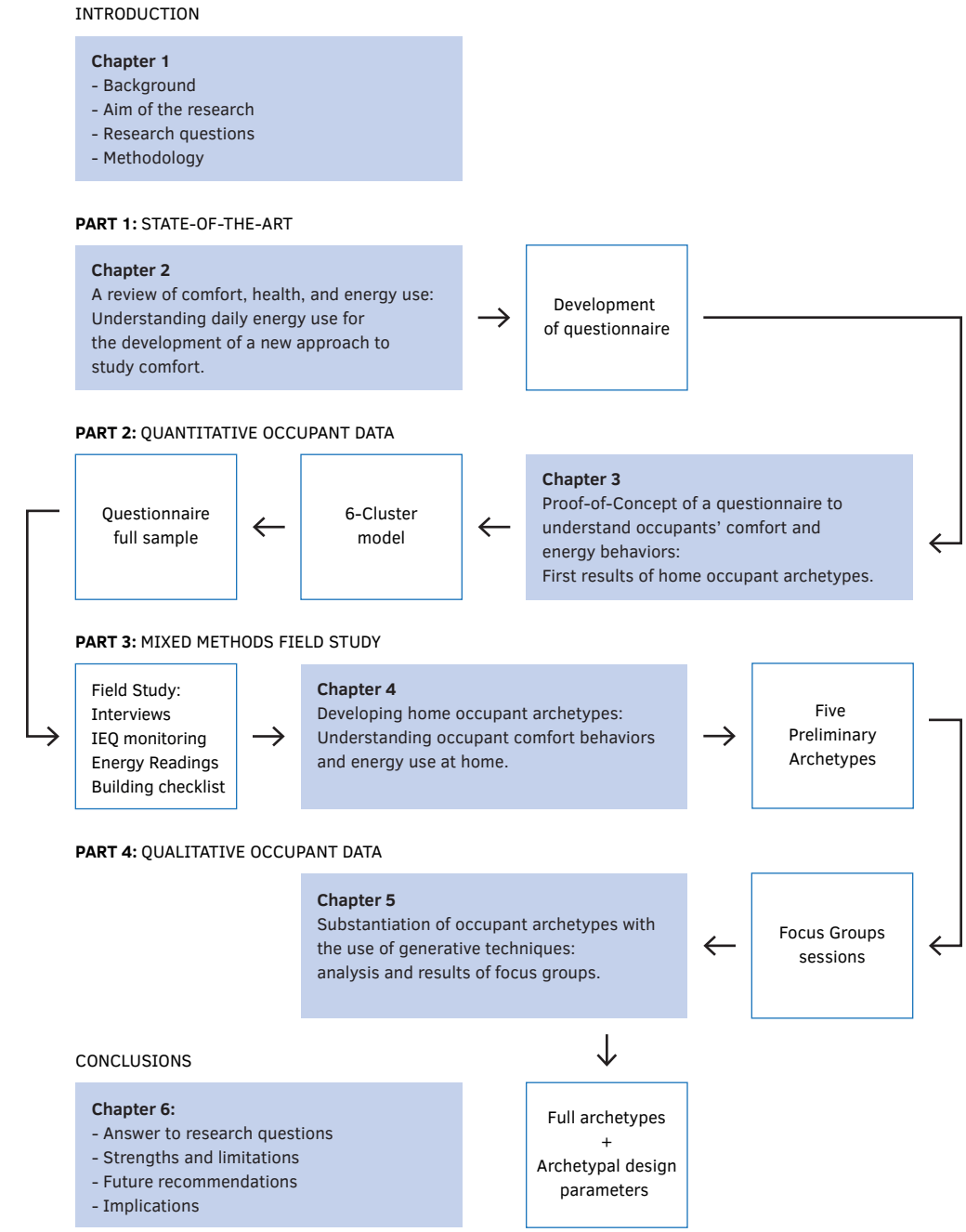


FIG. 1.3 Outline of thesis

TOC

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maar stokte door onduidelijkheid bij de ontwikkeling van Arnhem-Zuid. Het besluit om een groen hart te maken wordt pas in 2008 in een bestuursovereenkomst bekrachtigd. De naam: Park Lingezegen (naar riviertje de Linge en diens kleinere watergangen of zegen). Vier gemeenten, de provincie en het waterschap zetten hun handtekening. Berdie Olthof (Feddes/Olthof) krijgt de opdracht een masterplan te maken voor een landschapspark met verschillende functies: natuur, landbouw,

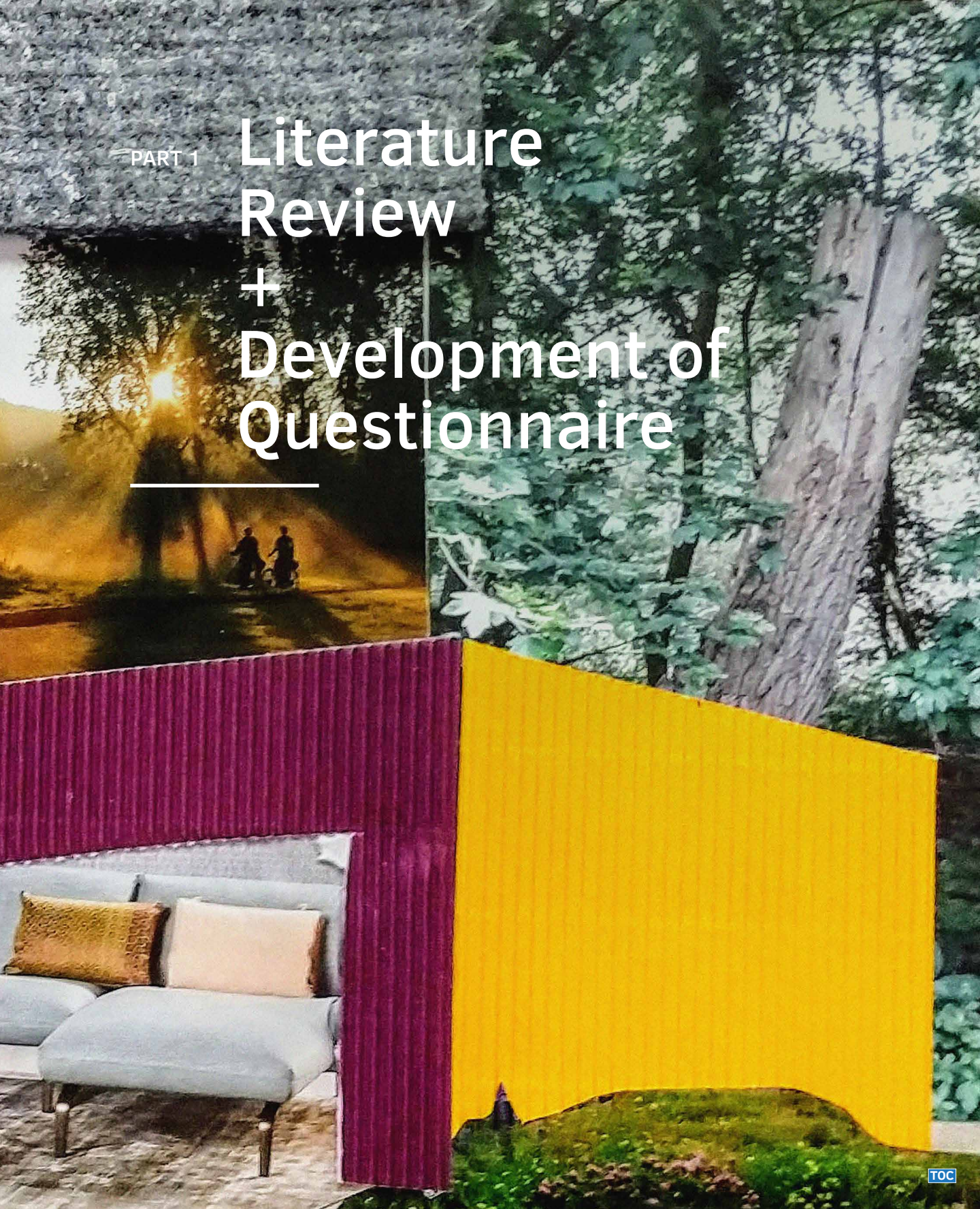
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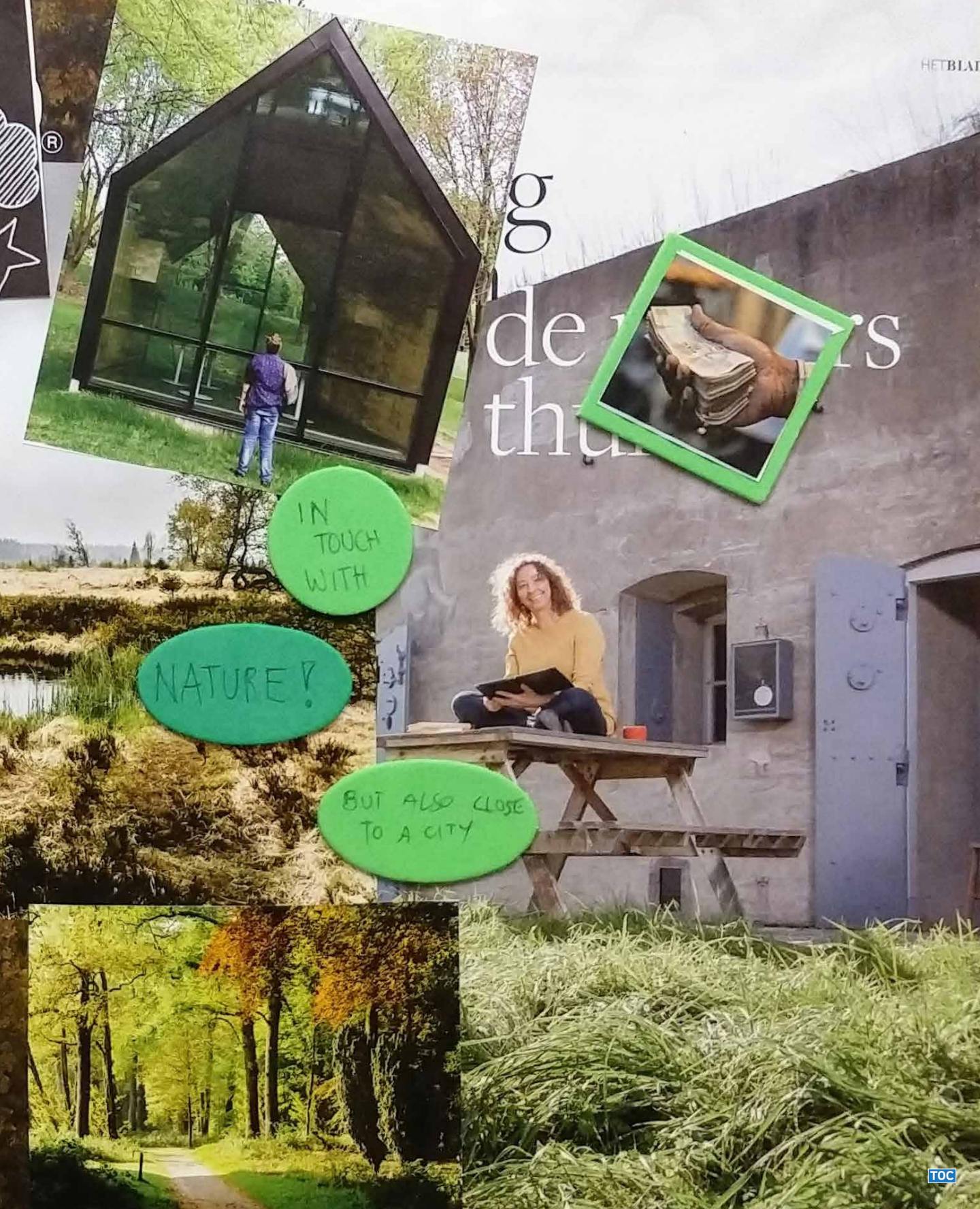
TOC



PART 1

Literature Review + Development of Questionnaire

TOC


IN TOUCH WITH
NATURE!
BUT ALSO CLOSE TO A CITY

2 Introducing Comfort, Energy, and Behaviours

A review of comfort, health, and energy use: Understanding daily energy use and wellbeing for the development of a new approach to study comfort

Marco A. Ortiz, Stanley R. Kurvers, Philomena M. Bluyssen

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A review of comfort, health, and energy use: Understanding daily energy use and wellbeing for the development of a new approach to study comfort

ABSTRACT There is a need for reducing dwellings' energy consumption while maintaining a comfortable and healthy indoor environment. This review was performed to provide a steppingstone for identifying new methods for studying everyday home energy use and comfort. First, an overview of comfort is given as seen from different disciplines, depicting the subjective and multidimensional nature of comfort. This is followed by the biological component of comfort, reflected as an emotional, behavioural, and physiological reaction to environmental stimuli. Subsequently, links between comfort, health, and wellbeing are introduced. The second part of the review focuses on energy and buildings, with the connection between energy and behaviours-detailing possible explanations of performance gaps, and the pathways from energy to health. To conclude, human sensation of comfort is more complex than the perception of thermal, acoustical, visual stimuli, or air quality environment. Comfort is a reaction to the environment that is strongly influenced by cognitive and behavioural processes. Habits and controllability have been identified as paramount in the links between comfort and energy consumption. In this holistic view of comfort linked to health, comfort is referred to as 'wellbeing'. The first steps for new directions of the study of comfort and energy are presented

KEYWORDS energy consumption, habits, controllability, comfort behaviours, health, design thinking.

2.1 Introduction

Comfort has traditionally been studied from the perspective of the physics of the environment and the physiology of the occupant, in terms of four factors: thermal comfort, acoustical quality, air quality, and visual quality. Codes and standards for each of the factors have been established, and technologies and systems are being engineered in order to satisfy such standards in a presumably energy efficient manner. The challenge with such an approach is that individual standards for each of the factors are not meant to be used as human's global experience of comfort, which causes challenges and risks (Claude-Alain Roulet, Flourentzos Flourentzou, et al., 2006).

Additionally, there is a need to provide energy efficient buildings that are also healthy; which is not always the case (IEA, 2013). Occupant behaviours seem to be responsible for the discrepancies between actual and theoretical energy consumption (i.e. rebound effects, performances gaps). As a result, it was found necessary to perform a literature study on the links between energy use, comfort-making, and health, in order to identify a potential new approach in the study of the interactions between those topics.

2.2 Materials and Methods

An extensive literature review was performed in the topics of health, comfort, and energy use, with a focus on the interactions between the occupant and the environment. Three topics form the focus of this literature review: the first being comfort as a cognitive-behavioural process, specifically reflected with the concepts of sense of control, habits, and emotions. The second topic deals with energy in buildings: first providing the current consumption trends in the Netherlands –chosen as a country-specific case-study-, followed by a discussion on the rebound effect and performance gaps. The third, discussing human factors in terms of energy habits and the relation with health.

The aim of this paper is to provide better understanding of the several factors influencing energy usage, from a perspective of the psychological and behavioural interactions of the occupant and its environment. Many of these interactions –

whether conscious or unconscious- are performed to achieve homeostasis (i.e. comfort, neutral state, less discomfort, etc.). These behaviours are here referred to as 'comfort-making activities', and have been specifically identified as controlling the environment and habitual actions –actions that enable psychosocial homeostasis. By understanding the energy use through this approach, it is intended to set forward a conceptual framework for the research of energy use.

The review was performed by searching in engines such as Google Scholar, ScienceDirect, and Web of Science. The selection of the literature was limited to articles from peer-reviewed journals and conference proceedings. For the health section, a table was made in which the articles are categorized according to their strength of evidence. Data from academically published books and Dutch websites of energy and economic affairs were also included. Because of the interdisciplinary nature of the review, in order to find the same topic but in different fields, the field in question was added in the search in quotation marks (i.e. "nursing", "psychology"). The different tags used for the research fields are shown in Table 2.1.

TABLE 2.1 Research keywords

Term (construct)	AND / OR	Term (location)	AND / OR	Discipline
Behaviour		Domestic		Environmental Psychology
Comfort		Residential		Sociology
Emotions		Home		Nursing
Energy Use		House		Indoor environmental quality
Energy Consumption		Housing		Ergonomics
Energy Expenditure		Environment		Design
Wellbeing		Dwelling		Healthcare
Habits				Holistic
Controllability				Evolutionary biology
Homeostasis				Human centered Design
				User centered Design
				Emotional Design

The collection of information was used to illustrate the current situation in the domains of health and comfort in the built environment and the relationship with energy use from a multidisciplinary perspective. By being acquainted with the current situation, intervention points were identified for the study of comfort and energy, in order to suggest a possible new approach for the understanding of residential comfort and energy expenditure.

2.3 Results

2.3.1 Comfort

2.3.1.1 Comfort definitions by discipline

Due to the subjective nature of comfort, individual fields that need to investigate comfort have developed their own definitions of the concept. To gain a multidisciplinary and comprehensive understanding of what comfort is, the definitions on the fields of IEQ, healthcare, and ergonomics are presented, along with a 'domestic' and a holistic definition which have been put forth.

Indoor Environmental Quality

In the IEQ literature, comfort is viewed from a physiological-technological perspective and described through the following parameters: visual (with aspects such as view, illuminance, and reflection), thermal (air velocity, humidity, and temperature), acoustical (control of unwanted noise, vibrations, and reverberations), and air quality (smells, irritants, outdoor air, and ventilation) (Bluyssen, 2009) . There exist international and country-specific standards (for a few chemical substances) and guidelines are available for IEQ factors. Energy consuming systems and products are developed so that they can contribute to achieve the standards or guidelines. For thermal comfort, the adaptive approach has been proposed; comprising a model for studying thermal comfort through the adaptive principle: "if a change occurs such as to produce discomfort, people react in ways that tend to restore their comfort." This is achieved through "adaptive actions" enabled by "adaptive opportunities" (Brager & de Dear, 2001; Nicol, Humphreys, & Roaf, 2012) .

Healthcare

In the healthcare literature, comfort is defined as a concept of two dimensions (Kolcaba, 1994). The first dimension consists of three states: 'relief', 'ease', and 'transcendence', which have to be experienced by a patient to be comfortable. Relief is the feeling of having had specific needs met, ease is the state of calm and contentment, and transcendence refers to the state where the patient goes beyond

problems or pain. The second dimension of comfort deals with the context where comfort happens. The context can be physical –relating to bodily feelings -, it can be psychospiritual –relating to the inner self-, it can be social –relating to family or cultural relationships, or it can be environmental –dealing with light, noise, temperatures, sensations (Kolcaba, 1994).

Ergonomics

Due to the wide scope of the domain of ergonomics, several definitions exist. A general definition is that when a product is comfortable, performance increases: comfort is "an ease and contentment with the environment or product that facilitates performance" (Kolcaba, 1991). The literature of ergonomics and comfort is dominated by seating comfort. For chair ergonomics, comfort is defined with factors related to "aesthetics and plushness, relaxation, well-being, and relief and energy" (Helander, 2003) .

Holistic

Some authors have put forth integrative definitions of comfort which also include a cognitive dimension; for example Slater (1985) has proposed "a pleasant state of physiological, psychological and physical harmony between a human being and its environment" (Looze, Kuijt-Evers, & Dieën, 2003; Slater, 1985). De Looze et al. have identified that in comfort definitions across disciplines, three elements are certain and recurring: 1- comfort is a construct of a subjectively defined personal nature; 2- it is affected by factors of a various nature (physical, physiological, psychological); and 3- it is a reaction to the environment.

Domestic

Heijs and Stringer have also proposed specific elements of comfort in the domestic context, implying the place of residence (Heijs & Stringer, 1987). These are perceptual, interactive, facilitative, and personalization comfort. These elements are related to contextual affordances that enable the occupant to carry out the behaviours according to their social and personal needs and to give meaning to the place through emotional attachment and self-identification.

For a general overview of the scope of environmental factors and human factors covered by comfort in different domains, refer to Appendix B, Table 1: Scope of comfort by discipline and by human and environmental factors.

2.3.1.2 Evolutionary Biology, Emotions, and Behaviour

To show the link between comfort and energy consumptions, in this section, the biological origins of comfort are presented, along with the relationship between the comfort and emotions, and that of emotions and behaviours.

Evolutionary biology

Humans are the result of a several million year evolutionary process in the East African savanna. Therefore, there are still physiological, cognitive, and behavioural legacies of the evolution present in modern human. The physiological characteristics of humans reflect its evolution in the savanna: an environment with rainfalls, grasslands and forest mix, mild variating temperatures, and predators. The transition from the savanna lifestyle to today's environment occurred in an evolutionarily too brief of a period for changes to occur, rendering modern humans physiologically and psychologically identical to their first human ancestors (Dunn, 2011) . As a result, humans are in many respects maladapted to their environment. In spite of not having any modern technologies, early humans dispersed around the globe and managed to live from polar to desert regions, due to two basic strategies: appropriate clothing –the second skin- and appropriate shelter -the third skin. These extra skins have allowed compensating for and adapting to the more extreme climatic conditions and still achieving acceptable conditions (Dunn, 2011; Fuchs, Hegger, Stark, & Zeumer, 2008) .

Emotions

One of the results of evolution is emotions. Emotions are specific states that increase the adaptability and ability of a person to cope with a specific situation, which may be a threat or a benefit to their wellbeing. One model that explains emotion elicitation is the three-level processing model (Norman, Ortony, & Russell, 2002; Ortony et al., 2012) . The model explains that the feeling of an emotion emerges from three reactions: reactive, routine, and reflective; each of which is elicited by different aspects of the environmental stimulus. The reactive reaction deals with immediately perceptible sensory characteristics of the stimulus: appearances. This is a biology-driven reaction, in which reasoning does not happen: it allows to unconsciously assessing the stimulus as a threat or a benefit. The routine reaction involves automatisms, such as habits, from long-term memory and expectations during active interaction with the stimulus: the predictability of the performance and usage. Finally, the reflective level involves the fully felt emotion: the conscious appraisal and rationalization of what the stimulus and event means to the person, in terms of relatedness to the values, beliefs, and needs of the person.

Behaviours: Emotions are tightly linked to behaviours and decision-making. Feeling emotions enables making decisions and motivating behaviours. It has been shown that people with lesions affecting their emotional system are unable to make decisions or behave accordingly, in spite of being psychologically and behaviourally normal in every other aspect (Bechara, 2004; Damasio, 1994). Some types of behaviours are controlling the environment (controllability) and exercising habitual actions (habits).

Behaviours

Habits

Habits are part of the routine level of response, and are defined as "learned sequences of acts that have become an automatic response to specific cues and are functional in obtaining certain goal or end states" (Verplanken & Aarts, 1999) . They are the result of associative learning from environmental or contextual cues and of responding to such cues through procedural memory. Thus, habits are a type of behaviour that is unconscious and automatic, and that are repeated when a particular stimulus is perceived (Wood & Rünger, 2016) . Habits are formed by the initial motivation to achieve a goal within a context and with cues. With repetition, perceiving the cue elicits automatically the behavioural response to mind, which is normally performed. Further repeating the habit strengthens it, and even when the original goal or reward is not needed, habits will still be triggered by the contextual cues. This occurs since carrying out a habit activates the dopamine systems, reducing cortisol, which as a result strengthens the habits further, due to the experienced pleasure. Thus, performing a habit only by itself produces feelings of pleasure. In addition, habits allow the individual to achieve goals in a quick and effective way that requires minimal thought (Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005; Maréchal, 2009; Wood & Rünger, 2016). Many elements of habits overlap with those of comfort, such as elimination of negative affect, reduction of the stress hormone, and controllability of the environment. Repetitive, stable, and predictable environmental cues that elicit habits also indicate the degree of feeling in control over environment.

Controllability

Sense of control encompasses the concepts of "perceived" control and "actual" control; perceived control being the level of control a person believes to have, while the actual control is the behavioural exertion of control by the individual. Controllability evolved from the need of protection against predators. In evolutionary terms, shadows, movements, shapes that could be a threat to the human's life were uncontrollable and caused a fight-or-flight response (Dunn, 2011). To this day

stimuli reminiscent of threats still elicit the chain of hormonal reactions, culminating in the fight-or-flight response. This response makes the human ready to fight against the threat or flee from it, which would typically last from a few seconds to minutes, and then the physiology and hormones would go back to a normal state. In the modern lifestyle, many ordinary stimuli associated with not feeling in control, still trigger the fight-or-flight response, however, in most cases, the person cannot rationally flee or fight the modern stressor (i.e. locked windows, neighbours, debts, leaks, etc.) (Dunn, 2011) . Thus, the stressor becomes a 'constant threat', and as a result, the hormonal and immune systems come out of balance due to chronic stress (allostatic load). Studies have shown that there is an association between the lack of sense of control and diverse stress-related health problems, such as depression, anxiety, high blood pressure, and weakened immune functioning (Marberry, 1995) . The feeling of being in control not only reduces stress-related health issues, it also increases the feeling of comfort, it makes people feel more satisfied, and in the workspace, workers feel more appreciated. Choices offered by the environment (i.e. operability of windows, decorating, privacy, and social interaction, cooking, etc.) afford the occupant to have a feeling of being in control. The need for control and choice are closely related. The presence of environmental choices enables a person to exercise control or to increase their perception of control over their environment, through behaviours that avoid undesirable results or through those that achieve desirable ones (Leotti, Iyengar, & Ochsner, 2010). Thus, when a person has choices and is able to decide, they may feel less stressed and more comfortable (Leather, Pyrgas, Beale, & Lawrence, 1998; Li, De Ridder, Vermeeren, Conrado, & Martella, 2013; Ong, 2013; Vink, 2004).

2.3.1.3 Environment and Health

This section deals with the existing evidence of environmental influences in mental health, particularly from the perspective of psychoneuroimmunology (PNI). One of the proposed pathways in which the environment influences mental and physical health is through the emotional responses the environment elicits in the occupant. In their turn, the emotions influence mental and physical health, as explained in the section. The first part, 'From Environment to Emotions', deals with the current evidence as to how the environment influences emotions. Examples in healthcare and office settings are provided, since research in the residential context is lacking. The second part, 'From Emotions to Health', shows the next part of the aforementioned process between "environment-emotions-health". It presents the biological processes that occur when positive emotions are present and what their effects on mental and physical health are.

The environment provides stimuli that elicit an emotional response in the person, which helps the person to cope with the situation. Therefore, environments have the potential of causing stress, but they can also have restorative effects, influencing wellbeing (Kaplan, 1995; Kellert, 2012; Russell et al., 2013) . PNI studies the interactions between health, mind, and environment, with the focus on the influence of psychological and social factors on human physiology, and thus, it examines the links between the environment, brain, behaviour, and the immune system (Zachariae, 2009a).

From Environment to Emotions

Most of the evidence that links environment to health and wellbeing comes from environmental psychology studies, healthcare environment design, and sick building syndrome research. The evidence in such studies is based on the prevalence of physiological symptoms, evidence of positive health outcomes, nature restoration theory, cortisol levels, depression, immune regulation, and attention restoration theory (Anthony, 1998; Cohen, Evans, Stokols, & Krantz, 2013; Cox, Burns, & Savage, 2004; Frumkin, 2005; R. Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Stokols, Grzywacz, McMahan, & Phillips, 2003; Williams, 1994). Healthcare design aims at making patients feel better to heal faster by reducing stress and increasing comfort, via environmental features, while in the office setting, productivity, creativity, and physical and mental health are the target to improve. In such studies, it is shown that environmental aspects have an effect on the mood of patients, workers.

From Emotions to Health

There is not only a link between environmental cues and emotions, but also one between emotions and health (Bluyssen, 2014a). Evidence indicates that positive emotions have an influence on both health and longevity (Diener & Chan, 2011). Positive emotions have been associated with lower blood pressure levels, as well as reduced inflammatory processes and neuroendocrine, cardiovascular and immune strengthening, while negative emotions can cause stress, anxiety, depression, and eventually damaging changes in the cardiovascular system (Chida & Steptoe, 2008; Sapolsky, 2005; Segerstrom & Sephton, 2010; Steptoe, Wardle, & Marmot, 2005). Similarly, negative moods contribute to a delayed healing from wound and infection, while it has been documented that angry people have weaker immune responses to vaccines, as opposed to optimists. Likewise, the prevalence of self-reported rhinitis has been found to be higher amongst students with recent negative life events (Bluyssen, Ortiz & Roda, 2016). One of the pathways from emotions to health occurs since negative emotions stimulate the production of pro-inflammatory

cytokines, which lead to inflammation. In its turn, inflammation unbalances hormonal production and damages the healthy reproduction of cells, linking this with cancers and a variety of diseases (Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002).

Therefore, humans react to stimuli in their environment. This reaction is first emotional, then behavioural. The emotion guides the behaviour –negative emotions (stress/discomfort/displeasure) will trigger behaviours whose purpose is to eliminate or reduce the negative stimulus of the environment. The behaviour -through either control or habit- serves as a tool to bring homeostasis: to reduce the stress (discomfort/unbalance) caused by the environment, and to bring the individual's state back to a neutral one (comfort/lack of discomfort). Finally, the aforementioned studies suggest the strong connection between the environment, human emotions, behaviours, and health. However, these types of studies are predominantly done in the office and hospital contexts, leaving a knowledge gap regarding the domestic context.

2.3.2 Energy in Buildings

Traditionally, energy technologies and occupants' behaviour have been treated as separate actors in the domains of indoor environment, energy engineering, and social fields (Moezzi & Lutzenhiser, 2010): in spite of more recent efforts to link them, by viewing energy consumption as something performed by individual rather than solely technologies, in a context of interrelationships between users, technologies, skills, social contexts. In the engineering fields, the focus is on the development of efficient technologies –reducing greenhouse gases, reducing cost, etc. In the social fields, the focus is on behavioural changes through campaigns, awareness, and information. As a result, on the one hand, governments and energy policies carry out campaigns with fines, public information, etc., to try to stimulate householders' behavioural changes. On the other hand, the building and technology industry strives to produce houses that are more airtight, more stable temperatures, and less energy-consuming technologies. The fact that the two domains work independently to achieve lower energy use, could be the underlying reason leading to discrepancies observed between actual and theoretical energy consumption (Barbu, Griffiths, & Morton, 2013; Chatterton, 2011; Dahlbom, 2009; Geels, 2005; Grin, Rotmans, & Schot, 2010; McKenzie-Mohr, 2000; Verbeek & Slob, 2006; Wilhite, 2008).

2.3.2.1 Energy and Behaviours

Theoretical vs. Actual consumption: While theoretical energy consumption calculations tend to ignore the part of the energy expenditure determined by the occupant's lifestyle (behavioural determinants), actual energy consumption is obtained from final energy bills and meters of the household building in question, reflecting the consumption of every single appliance and behaviour (Majcen, 2016). In 2002 in Europe, the European Performance of Buildings Directive was passed, introducing the Energy Performance Certification (EPC) labelling for residential buildings. The EPC model is calculated according to a methodology that considers insulation, heating, hot water and ventilations systems, and fuels used; therefore ignoring appliance use and human behaviour (Majcen, 2016).

The difference between the predicted consumption and the actual one is called "performance gap". In a study performed by Majcen (2016) shown in Figure 2.1, for electricity consumption, electric appliances are an ignored variable when making theoretical calculations. According to milieucentraal.nl, in the Netherlands, such appliances represent about 32.4% of the household's total electricity consumption (Milieucentraal, 2016). While for gas usage, the main ignored variable in theoretical estimations is 'cooking behaviours'. From the total energy consumption of a Dutch household, on average gas accounts for 67.3% of the total actual energy consumption, while electricity accounts for 32.7% (Majcen, 2016; Milieucentraal, 2016).

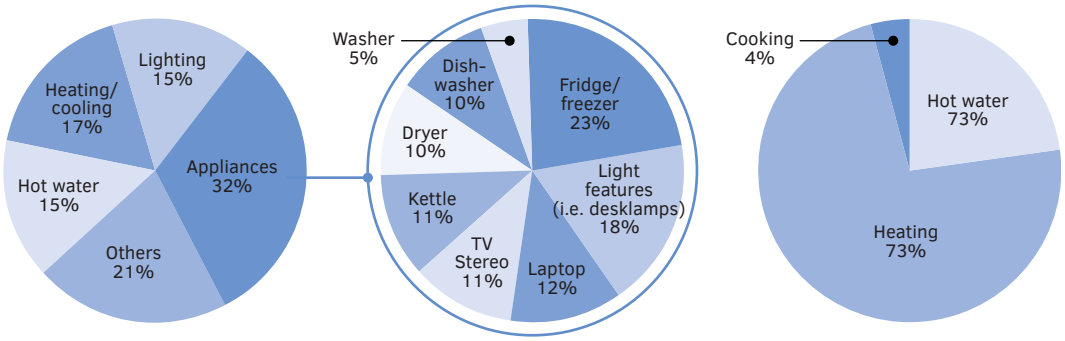


FIG. 2.1 Dutch electricity consumption and appliance breakdown and Gas consumption (adapted from Majcen, 2016; Milieucentraal, 2016)

TOC

In the 1980s it was estimated that human factors, such as attitudes of residents towards energy based on prices, environmental concerns, health concerns, and comfort, could influence up to 5% of the variation of consumption (W. F. van Raaij & T. M. M. Verhallen, 1983). Recently, at international level, the IEA identified three major causes of performance gaps: climate factors, building factors, and human behaviour. Different studies performed in EPC labelled dwellings have shown that occupant behaviour heavily influences energy consumption, and it has been shown that actual energy consumption is in every case higher than the predicted one (Bordass, 2004; Demanuele, Tweddell, & Davies, 2010). However, other studies have shown that, at least in the Netherlands, low energy labelled buildings 'consume' less than predicted, but the opposite occurs with energy-efficient residences (Majcen et al., 2013). Such behavioural determinants of consumption are interactions with services and technologies, as motivated by occupancy patterns, attitudes, and beliefs; all of which are correlated with the occupant's behaviours. The fact that such variables are not considered in estimations is likely due to the fact that the engineering and design process of buildings, systems, and technologies (from micro to macro scales, i.e.: knobs, buttons, interfaces, layout, spaces, automations, services, etc.) also tends to exclude such human factors: users' needs have to be understood by involving the user in the process (Berkhout, Muskens, & W. Velthuijsen, 2000; Dietz, Stern, & Weber, 2013; Huijts, Molin, & Steg, 2012; Midden, 2006). Yao and Steemers propose that occupancy patterns (number of occupants, sleep and wake times, and daily occupancy time) influence energy consumption. These patterns influence both physical and behavioural determinants of consumption. Physical determinants are factors such as heating, cooling, lighting, determined by characteristics such as dwelling size, design, systems, services, and climate, while behavioural determinants are factors such as frequency of use of appliances, systems (Yao & Steemers, 2005).

Similarly, the social practice theory contends that the centre of energy consumption is guided by social dynamics as ordered in time (Shove, 2004; Torriti, 2017). In other words, certain social practices are performed at specific times, and the fact of carrying them out, as a society, brings energy demand to a peak in a certain place. Social practices can be habits such as working, cooking, washing, or watching TV, each of which is generally performed at specific times in similar societies. Therefore, it is advocated that to understand energy consumption, it is indispensable to understand such social practices and their timing.

Energy and wellbeing

The relationships between energy and wellbeing are complex and involve many variables. However, generally by Western standards a 'good life' at home tends to translate into higher energy usage. One of the links between wellbeing and energy use in households is related to standard of living and quality of life: several energy-consuming activities improve wellbeing, such as maintaining liveable temperatures, refrigerating perishables, cooking, hot water access, lighting, and other technologies that bring convenience to occupants. It has been estimated that in less than one generation, expectations of comfort via central heating and air conditioning have become a norm. However, it has been proposed that energy savings can be achieved while still maintaining a high quality of life and wellbeing provided by the energy consuming services (Aune, Ryghaug, & Godbolt, 2011; Dietz, 2015; Waite-Chuah, 2012).

Energy and Habits

Recent findings show that most of everyday behaviours are guided by habits, especially when interacting with technology since technology acts as a contextual cue that triggers the habit. In the residential context replenished with energy appliances, it is assumed that it is more probable that humans will use "simple heuristics" or habits; since it is an environment with cues that do not require cognitive effort (Ehrhardt-Martinez, 2011; Jager, 2003; Maréchal, 2010; Pierce, Schiano, & Paulos, 2010). Another reason why habits are strong in the domestic context, is because, 'home' provides cues that are physical, social, and temporal, all of which enable habit creation and strengthening. Additionally, as in most cases, energy consumption is 'invisible' for the occupant, which strengthens possible unsustainable habits (Ji & Wood, 2007; Martiskaïnen, 2008). These habitual interactions occur with appliances but also with interfaces of systems –thermostats, lights, equipment, etc. - and those of the building envelope –windows, shades.

Because of the unconscious and automatic nature of habits, they have been shown to prevent a willing person to change into pro-environmental or more efficient behaviours, and thus, habits could make people act in ways that are opposite to their intentions (Martiskaïnen, 2008), without noticing. Finally, because of their unconsciousness, habits have been either overlooked or understudied in energy consumption research. Furthermore, in order to change habits into more sustainable ones, it is suggested that policies should tackle the tangible environmental cues that trigger the habits themselves. This is because the environmental characteristics have higher impact on energy consumption than other variables, such as attitudinal ones (Huebner, Cooper, & Jones, 2013; Verplanken & Wood, 2006).

2.3.2.2 Health and energy

The study of the relationships between home energy and health is complex, since there are several linking pathways, measurement of exposures, dosages, long term effects, as well as the multiple interacting, dynamic, and interdependent building and occupant factors (Barton, Basham, Foy, Buckingham, & Somerville, 2007; Howden-Chapman et al., 2007; Liddell & Morris, 2010; Nagasawa, Yamaguchi, Kato, & Shin-ichi, 2015; Rashid & Zimring, 2008; Thomson, Petticrew, & Morrison, 2001). As a result, there is still debate about the impacts on health of energy efficient homes. There is evidence that energy efficient homes, measures, or interventions modestly improve some aspects of physical health of occupants (Fisk, 2000; Maidment, Jones, Webb, Hathway, & Gilbertson, 2014; Thomson, Thomas, Sellstrom, & Petticrew, 2009; Willand, Ridley, & Maller, 2015; Wilson et al., 2014). Although research has been done on the effects of climate change and outdoor temperature on certain populations, this review focuses solely on the indoor environment and temperatures. It has been reviewed that thermal comfort improvements in homes seem to generate health improvements, specifically in those who suffer chronic respiratory diseases. In a similar vein, households capable of heating their homes are also linked to better health and social relationships, and lower school absenteeism (Thomson, Thomas, Sellstrom, & Petticrew, 2013). The limitations of such studies are that they focus on start- and endpoints without considering the network of factors, causes, and effects. For a full overview of those studies, refer to Appendix B, Table .2. Effects of energy efficient measures on health of occupants.

Airtightness has been encouraged by the European commission in order to satisfy energy standards. However, with airtightness, the indoor air quality of the dwelling could be at risk. High airtightness needs adequate ventilation rates and system maintenance. Inadequate ventilation in an airtight home can lead to increased dampness and humidity, and thus higher concentrations of biological, chemical, and physical contaminants (CO, NO2, CO2, formaldehyde, VOCs, radon, PMs, mites, moulds, etc.). These pollutants have been associated with several health risks, especially with the prevalence of respiratory and allergic effects both in children and adults (Mendell, Macher, & Kumagai, 2014; Sharpe, Thornton, Nikolaou, & Osborne, 2015; Sun & Sundell, 2013). Nevertheless, airtight buildings with properly maintained mechanical ventilation systems, especially for its efficiency in filtering ambient particles, could offer modest improvements in symptoms or health outcomes (Fisk, 2013; Leech, Raizenne, & Gusdorf, 2004). In the HOPE project it was found that there is a correlation between perceived comfort variables themselves, and between Building Symptom Index variables and comfort variables; suggesting that energy-efficient buildings with good indoor environmental quality and healthy occupants are possible, but the opposite also exists (Claude-Alain Roulet, Niklaus

Johner, et al., 2006). In the European Audit project, it was concluded that to improve indoor air quality without consuming more energy, source control should be applied to materials, systems, and polluting activities; thus, reducing pollutants while maintaining low ventilation rates (P. Bluyssen et al., 1995a).

2.4 Discussion and findings

2.4.1 Narrow view of comfort

In attempting to follow 'standards', the IEQ perspective of comfort tends to fall short when unavoidably combined with the standards required for energy efficiency, due to being limited to single parameters of the four IEQ factors (air quality, thermal, acoustical, visual) ignoring possible interactions as well as differences among people. The literature review shows that comfort is a wider and deeper phenomenon of subjective nature and contextual dynamism. Considering this, in this review, it may be better to refer to it as 'wellbeing'. This is because -as mentioned earlier- comfort-making activities are equivalent to the attainment of homeostasis, and thus imply the reduction of stress and consequently, the improvement of health. Holistic and domestic comfort definitions have also been put forward. Comfort is more than a physiological reaction; it is a subjective reaction to environmental stimuli, which can be behavioural, social, physiological, psychological, and physical, and that indicates harmony and neutrality with the stimuli.

These further dimensions of comfort are missing from the IEQ perspective. In IEQ, it seems that the current definition does not provide enough knowledge about comfort's behavioural quality: a crucial aspect when studying energy use. Although an adaptive model for thermal quality exists, in-depth analyses of the proposed "adaptive actions" seem to be lacking and are restricted to five types of actions: heat generation and loss (physiologically), regulating the thermal environment, selecting a different thermal environment, or modifying the body's physiological comfort conditions (moving, adjust layers, etc.) . As a result, this model falls short in both depth and broadness, being confined to thermal comfort and to the aforementioned types, while ignoring the investigation of the actual "adaptive activities" and "adaptive choices".

From the literature review, four main points can be concluded: firstly, generally, humans avoid discomfort and unpleasant experiences, and hence they are always striving (whether consciously or unconsciously) to change their present state towards a homeostatic state –thus a more neutral or comfortable one. As a result, many of the actions we do are wellbeing-driven: actions that can have effects on both health and comfort. Secondly, household energy consuming technologies are tools that allow occupants to achieve such comfort and wellbeing by performing the activities. Thirdly, energy consumption occurs when occupants interact with such technologies when they search for 'wellbeing'. Fourthly, habits and control actions are types of behaviours that particularly consume energy, and they are, to an extent and amongst other factors, influenced by the person's affective (energy) attitudes and emotions. These attitudes towards energy vary from person to person, and hence, behaviours are different amongst different people, while personal differences of comfort perceptions and thresholds exist. As a result, there is a need to understand energy consumption from a behavioural perspective, in relation to the 'wellbeing' motivations of such behaviours.

2.4.2 Gaps in knowledge

Humans experience their environment via many mechanisms, including the simplified sequence of 'senses-emotions-behaviours'. Behaviours enable the individual to change their current emotional state: a negative affect will motivate behaviour to change something in their environment and a positive one will motivate them to encourage their current behaviour. The behaviours that are pertinent to wellbeing and energy are sense of control and habits, in that, in the home environment, they tend to have as a secondary effect of the expenditure of energy. Moreover, the fact of exercising control and carrying out habitual routines is in and of itself stress relieving; affecting thus both the short-term feeling of comfort and the long-term health.

Habits have been identified as the primary behavioural cause of performance gaps; however, they have seldom been studied due to their unconsciousness and automaticity. Nevertheless, in order to reduce energy consumption, the IEQ and energy engineering fields would need to investigate such types of behaviour within the context of 'comfort' so that technologies are designed by considering occupants needs. Sense of control is another type of behaviour of relevance to wellbeing and energy; since being in control means to give choices to the user, choices that generally will influence the final energy output.

2.5 New directions

In this review, evidence suggests the need for a new approach in the study of comfort and energy consumption. “Comfort” is a multidimensional and subjective construct that varies across contexts; however, by looking at it from a biological perspective, comfort is the maintenance of homeostasis -a reaction to the environment, indicating the absence of environmental stressors, that is strongly related to health.

2.5.1 Conceptual Framework

From the results of this review, a conceptual framework has been developed (Figure 2.2), proposing that energy use is a consequence of trying to attain homeostasis (comfort, neutral state, lack of stress).

Consequently, in this framework, the focus lies on the behavioural expressions of comfort. The link between comfort and energy consumption lies in the active interaction of an occupant with energy consuming products, when trying to achieve this comfort –in particular through the exercise of control and habits. Behaviour is strongly influenced –amongst other factors- by emotions and attitudes, and therefore, these variables have been included in the framework. This is also done since, as presented in this review, habits are highly emotional (emerging from the routine level of emotions) and counter-attitudinal (cognitive), due to their unconscious nature.

The feeling of being in control arises by exercising choice, enabled by the presence of environmental choices, while habits are automatic, unconscious, and repetitive behaviours triggered by environmental cues. Such behaviours not only allow the person to cope with stressors and modulate their emotional status towards a more desirable one, but exercising habits and control is also rewarding by itself. “Comfort” as seen from this wider perspective encompasses the subjective feeling of positive emotions and reduction of stress, and as a result, it is beneficial to the individual’s general wellbeing. However, health is also influenced by several factors in the indoor environment, especially in energy efficient homes.

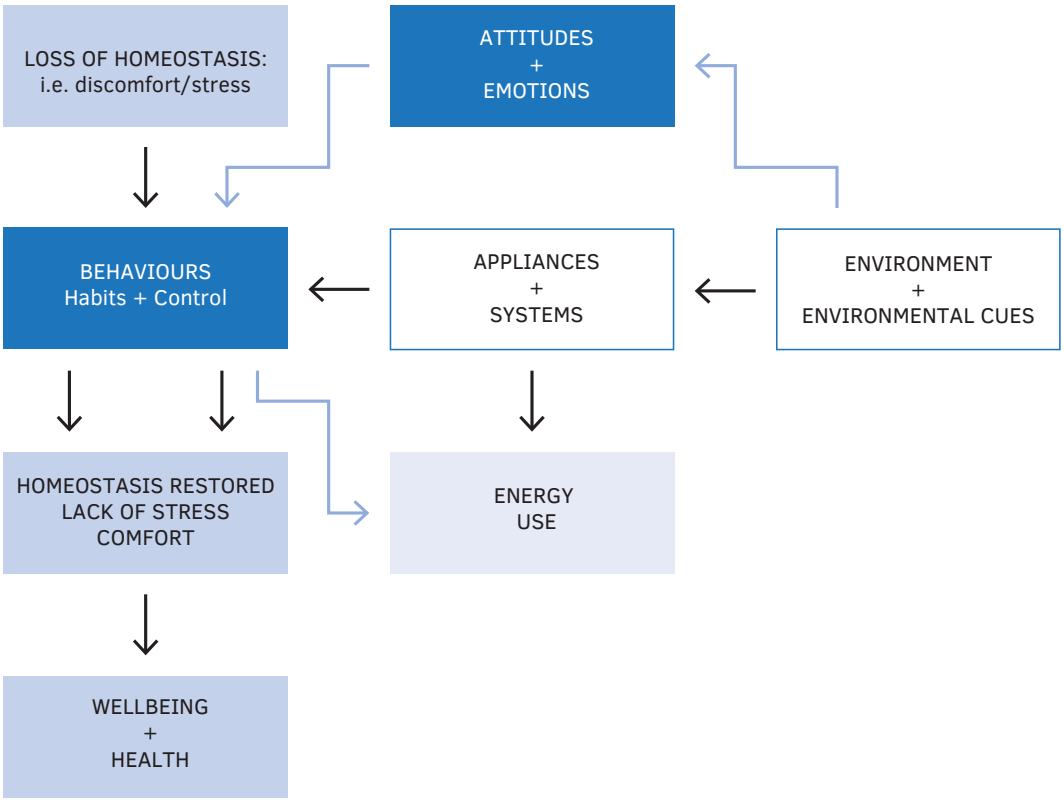


FIG. 2.2 Conceptual Framework: Loss of homeostasis (discomfort, distress) triggers the occupant to find again a more neutral state (i.e. comfort). This is performed by manipulating their environment (via interaction with appliances, systems) through behaviors (habits or control). Behaviors are to an extent guided by emotions and attitudes. Finally, when homeostasis is achieved, health and wellbeing are achieved in the long term. The interaction with the environment results in energy use.

2.5.2 Methodological Framework

From the conceptual framework, it is proposed to tackle wellbeing (comfort and its links to health) and energy from the perspective of the occupant, and more specifically, their comfort-making behaviours. Because not all occupants have the same needs, values, behaviours, or comfort levels, as a first step, it is proposed to conduct a specialized survey. The purpose of this survey is to find out different occupant profiles, based on their comfort and energy behaviours, and especially the key types of behaviour pinpointed in this review: habits and control.

TOC

To achieve so, the survey has to include questions about occupants' emotions (since they guide behaviour), attitudes, and health status. This should be continued by questions about occupants' energy-consuming habits and the strength of such habits. Finally, it has to include the levels of control that occupants need to have over their home environment.

By understanding these five factors (attitudes, emotions, health, control, and habits), which are factors that influence behaviours and that compose important dimensions of 'wellbeing', it should be possible to shed on light on whether there are different types of occupants, and where the differences lie.

The contribution of such an approach is to facilitate the identification of occupant types for the first steps of the engineering process of residential energy consuming technologies (appliances, control systems) but also to contribute to a more comprehensive understanding of comfort for IEQ. The goal of this is to be able provide residential environments –including systems and appliances- that support specific type of users, in terms of their behaviours and needs, so that energy consumption is reduced, while providing 'customized' and optimized wellbeing -comfort and health-.

2.6 Limitations

The limitations to this review can be categorized as both practical and methodological. The practical limitations lie in the fact that as it is based on the disciplines of the social sciences, namely behavioural psychology, the theories explained are not rigid and definite, but they are based on tendencies. The methodological limitations lie in the fact that there is a lack of research of the topic in the residential context. Theories such as that of the "three-level of emotion" tend to be used solely in the product design context, while the psychoneuroimmunological approach to wellbeing is as of now non-existent in the home context. Therefore, as social sciences are based on tendencies, changing the 'context' variable might alter the expected and known outcomes of the current tendencies. This is however, the reason why this review was performed, as well as why a new research approach is presented in the form of a methodological framework.

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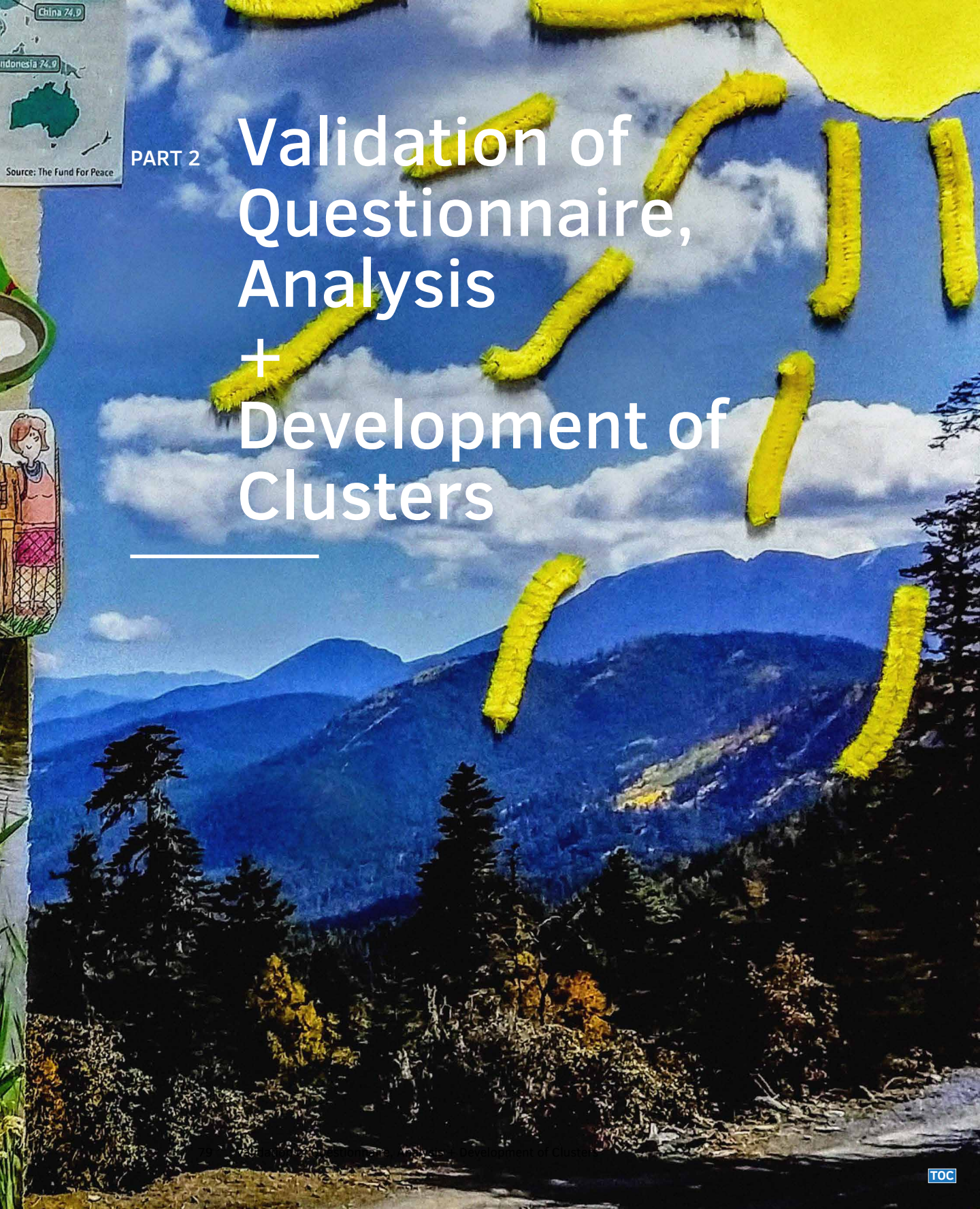
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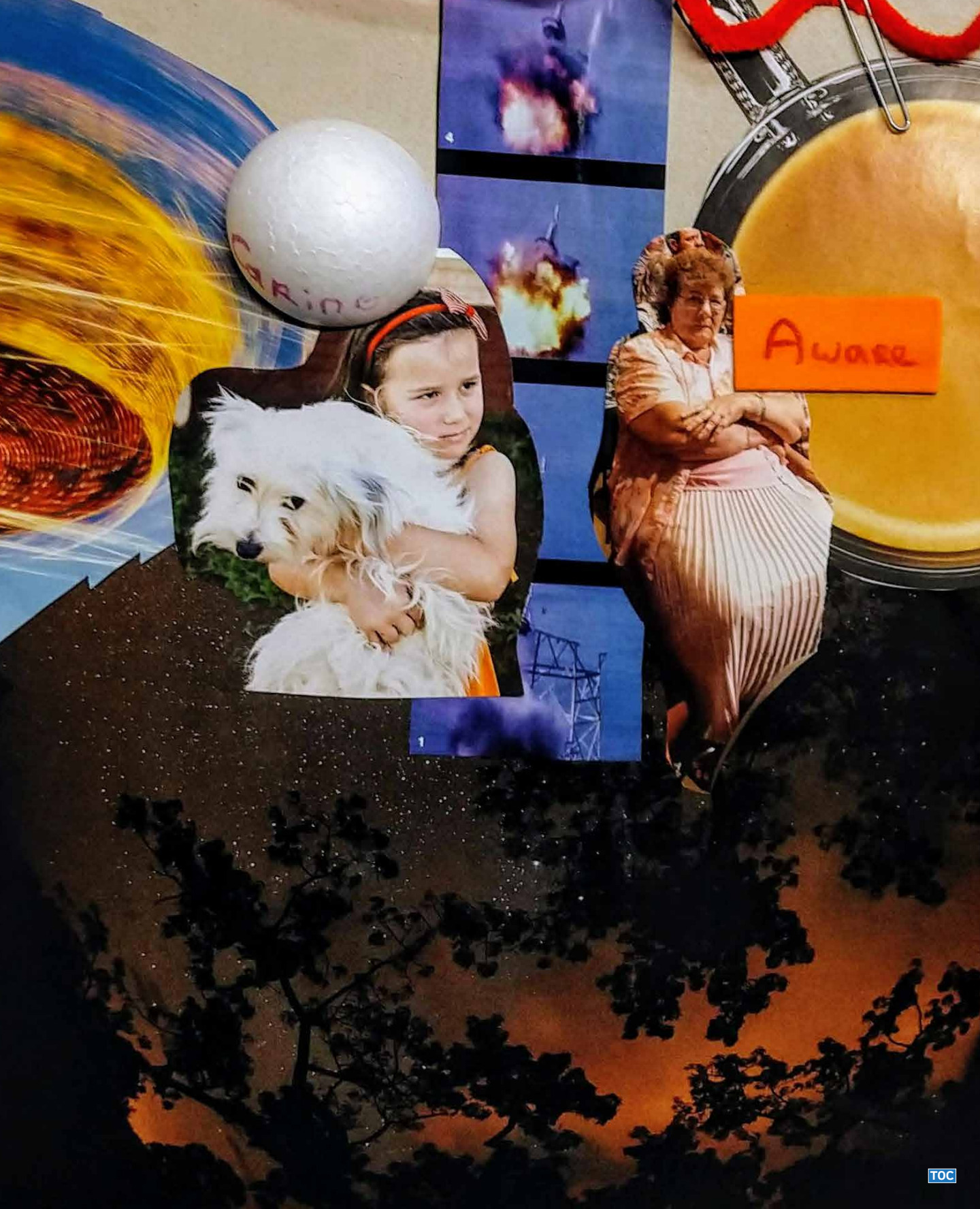
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Mexico 70.4
Sierra Leone 91.0
Liberia 95.5
Brazil 63.3
Nigeria 103.5
S. Sudan 113.8
Botswana 63.5
Yemen 111.5
WORST: Somalia 114.0
Rwanda 91.3
Congo 110.0
Fragile States Index score
2016
<60.0
60.0-89.9
90.0-99.9
100.0+
kijk



PART 2

Validation of Questionnaire, Analysis + Development of Clusters



TOC

3 Questionnaire testing, validating, and preliminary results

Proof-of-concept of a questionnaire to understand occupants' comfort and energy behaviours: First results on home occupant archetypes

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Proof-of-concept of a questionnaire to understand occupants' comfort and energy behaviours: First results on home occupant archetypes

ABSTRACT

This paper demonstrates the effectiveness of the TwoStep cluster analysis and the development and first results of a new questionnaire for measuring comfort, health, and energy habits. The justification for the questionnaire is to consolidate questions of six specific domains about occupants' energy consumption patterns, from the behavioural and psychological perspectives into one instrument.

The questionnaire was developed from a literature review, iterative conceptualization, and testing. The resulting instrument was administered to a sample of home occupants, comprising of bachelor students of Architecture of the Delft University of Technology. The objective of the study was to examine the effectiveness of the TwoStep cluster analysis to produce occupant profiles. 316 emails were sent out inviting participants to complete the questionnaire.

With the TwoStep cluster analysis, it was possible to distinguish six different archetypes of occupants based on their behavioural characteristics. These were the Relaxed Optimists, Unconcerned Indifferents, Restrained Sensitives, Positive Absolutists, Incautious Negativistics, and Resigned Savers.

The results provide promising evidence of the questionnaire's potential to distinguish different occupant energy-consumption profiles based on distinct psychosocial domains in a single and concise instrument, while also showing that the analysis method is appropriate for the type of variables gathered. The value of recognizing these profiles allows for a better understanding of occupants' differing energy consumption patterns in their homes and tailoring interventions to their specific needs.

KEYWORDS

residential, occupant segmentation, energy use, questionnaire, comfort behaviour

3.1 Introduction

To ensure a future with lower energy consumption, there is the need to address both technologies and human behaviour. However, an unequal amount of research and development has been addressed to the fields of energy engineering for the development of more energy efficient technologies (Gaffigan, 2008; Sovacool, 2014). Part of the issues is that traditionally in the development of comfort-providing technologies, comfort is limited to single parameters of the four IEQ factors, therefore ignoring interactions between factors as well as differences between comfort receivers. In spite of technological advancements, energy consumption does not seem to decrease at the rate it should (Majcen, 2016). This phenomenon is likely due to the behavioural component of energy consumption, which remains underinvestigated (Ortiz, Kurvers, & Bluyssen, 2017). Several behaviours performed at home can be considered comfort-making activities. This is because most activities carried out at home, are done to bring one's current state into a more neutral one, a process called homeostasis. As a result, many of those activities result in the reduction of stress (Ortiz et al., 2017). Therefore, it is imperative to better understand occupants' behaviours as well as the motivations behind such behaviours. In behavioural terms, the motivations behind behaviour can be divided into needs, attitudes, and emotions. Additionally, it has been determined that two particular types of behaviour are of importance in comfort-making -while also being understudied- these are controllability actions and habits. Exercising both control and habits is stress relieving; however, due to the unconscious and automatic nature of such behaviours, they remain understudied (Ortiz et al., 2017). To better understand occupants' behaviours in their homes, the motivations for such behaviours, and the relationships between behaviours, energy use, and comfort and health, a comprehensive questionnaire was developed. The questionnaire was administered to a sample of home occupants, and analysed with a cluster analysis method. Thus, the aim of this study was to 1) develop a questionnaire that enables the understanding of psychobehavioral constructs of occupants in terms of interactions with energy consuming technologies in the home context. In addition, 2) to determine whether it is possible to define homogenous groups based on the respondents' attitudes towards energy, emotions to home environment, locus of control in the home, and needs by using the Two Step cluster analysis method.

3.2 Method

3.2.1 Questionnaire

According to Ortiz et al. 2017, it is proposed that 'energy use', and more precisely the interactions between occupants and energy-consuming technologies, are a consequence of striving for homeostasis –a term used in this framework to define a neutral state, lack of physical and psychological stress or discomfort. As a result, the questionnaire focuses on the behavioural expressions of homeostasis and the intentions and motivations behind such behaviours. The constructs that culminate in behaviour that were chosen to be assessed in the questionnaire, as well as the seven sections composing the questionnaire, are presented and defined in Table 3.1.

These sections are a combination of several instruments adapted for this study. One of the main challenges for the creation of the questionnaire was to produce variables that measure the different constructs while being context-specific –the context of the home. Therefore, the already-validated instruments had to be adapted. This adaptation was performed by adjusting the wording of current questionnaires with the specific context of this study, namely the items found to be important for psychosocial and physiological homeostasis. The general characteristics, the attitudes, and the affordances questions were produced without the use of pre-validated questionnaires, while the health section was unaltered from the OFFICAIR study questionnaire (P. M. Bluyssen et al., 2015).

Based on these constructs, a total of fifteen major items were identified in the literature as elements that enable occupants to achieve social, psychological and physiological homeostasis, namely cleanliness and orderliness, IEQ factors (air quality, thermal, acoustical, visual comfort), control of climate, relaxation, personalization, freedom of expression, freedom of action, hobbies, privacy, mood of home, size, and cooking. The fifteen elements were then adjusted for each construct into questionnaire items. Depending on the constructs, some of the items were merged with the goal of gathering relevant and coherent data pertaining to the construct in question. The final items for each of the constructs are shown in Table 3.2. This resulted in eleven items for habits and affordances, and nine for control (for both internal and external).

TABLE 3.1 Questionnaire sections and description of instruments upon which they are based

Section	Definition	Composition of questions
Personal and building characteristics	General demographic characteristics about the respondent and their home.	Age, gender, nationality, home location, size, number of rooms.
Locus of control	Belief of control over outcomes: a spectrum ranging between 'internal' (based on the individuals' own behaviours) and external (due to circumstance, luck, other people) (Lefcourt, 2014).	9 statements for External and 9 for Internal residential control beliefs, adapted from the Locus of control scale by Levenson (1981)
Emotions	Affective conditions that are the reaction to something; they influence an individual's motivations to act in certain ways (Ortony et al., 2012)	14 positive and negative emotions, based on the PrEmo2 questionnaire by Laurans and Desmet (2012)
Health	Health status and symptoms adapted from the OFFICAIR project questions on health and symptoms by Bluyssen et al. (2015).	18 diseases or conditions and 11 symptoms related to sick building syndrome, with a follow up question of whether the symptom is related to indoor environment.
Affordances	"Offerings or action possibilities in the environment" (McGrenere & Ho, 2000)	Elements of the home which the respondent finds or not important for their subjective feeling of comfort. 11 items in 5-point Likert scale
Attitudes towards energy	"a learned, global evaluation of an object (person, place, or issue) that influences thought and action." (Perloff, 2010)	Willingness to change behaviours and efforts to carry a sustainable life. Semantic differentials rated with a 5-point Likert scale were developed, from questionnaire construction from Ajzen (Ajzen, 2006).
Energy-consuming habits	A counter-intentional and not fully-conscious form of behaviour performed as an automatic response to specific contextual cues and that helps to attain a goal or state (Wood & Rünger, 2016).	From Maréchal's (2010) (Maréchal) adaptation of the Self-Report Index of Habit Strength, by Verplanken and Aarts (1999) (Verplanken & Aarts, 1999)

TABLE 3.2 Constructs and related Items retrieved from literature relating to psychosocial and physiological comfort

	Habits	Control	Affordance
Physiological	– Cleaning up	– Cleanliness and orderliness	– Clean and order environment
	– Warming up – Freshen up	– Climate (daily basis control of ventilation and temperature)	– Appropriate air freshness – Appropriate temperature – Appropriate acoustical environment – Appropriate lighting
Psychological	– Cooking		
		– Atmosphere (long term control of climate)	– Control systems of climate
	– Relaxing	– Choice for relaxing	– Possibility for relaxing
	– Personalizing the place	– Personalization/identification	
	– Socializing in person – Socializing online – Hobbies	– Possibility for performing activities	– Freedom of expression – Freedom of action
	– Create privacy	– Possibility for privacy levels	– Appropriate privacy
	– Create the mood	– Possibility of changing mood for occasions	
		– Possibility of controlling layout	– Appropriate layout and sizes

3.2.2 Instruments

Locus of control has been identified as a main contributor to psychological wellbeing. This is because control beliefs are important for coping with everyday stress as well as life transitions. The locus of control scale by (Levenson, 1981) was used since it is the best established questionnaire for measuring an individual's locus of control, having been used in several fields, including nursing and housing for the elderly (Oswald, Wahl, Martin, & Mollenkopf, 2003). It was adapted for the domain of the home environment, thus, by utilizing concepts of the immediate residential environment, social support through the home, as shown in Table 2. Based on this, 18 statements were generated. The formulation of these items was based on the "Internal Control" and "External Control" dimensions of the original instrument, with nine items per dimension (i.e. Internal control: "It is up to me whether my home is kept in a tidy and clean state". External control: "I can't completely control the cleanliness and tidiness of my home: they are the result of time"). Items were assessed on a five-point scale, with a high score indicating higher degree of perceived control.

Habits have been identified as adaptive behaviours that are semi-unconscious, repetitive, goal-oriented, and environment dependent (Wood & Rünger, 2016). Habits are performed to achieve a psychological reward, and as a result, they have been shown to play an important role in stress. In this study's questionnaire, an adapted version of the Self-Report Habit Index by Maréchal (2010) was used. This version was used since it has been validated in previous questionnaires for people's habits in relation to energy use. This scale is composed of four items denoting the automaticity of habits (i.e. "In general Behavior X is anchored in my practices"; "…I do while being able to think of other things"; "…would be difficult to change", etc.). This is done for each of 11 behaviours identified in the housing literature to be common house habits (i.e. cooking, cleaning, light control, etc.).

Behavioural theories contend that emotions are an important contributor to human behaviour and health, and are strongly linked to comfort, since emotional, behavioural, and cognitive processes interact with the nervous and immune systems (Zachariae, 2009b). The instrument used for this topic was the PrEmo2 by Laurans and Desmet (2012) a non-verbal emotion self-report tool. Although several tools exist for assessing people's emotions, this instrument in particular is one of the few using a non-verbal method, while also being specifically developed to assess one's emotions towards a product or object. It is used to describe users' extent of emotions in relation to their experience of interaction with a product. It was adapted to reflect emotions in relation to the home. The tool covers four domains of emotions: general wellbeing, expectation-based, social context, and material context (Laurans & Desmet, 2012). Twelve emotions are depicted, half of them positive and half negative emotions, which are to be rated on a 1 to 5 scale, with a high scale reflecting strong feeling of the particular emotions and 1 not feeling it at all.

Attitudes can be divided into two dimensions: emotional and cognitive, the former being unconscious, the later conscious. The emotional dimension refers to the individual's feelings in response to the idea of energy, while the cognitive dimension refers to an individual's beliefs about energy. The questions were developed with the guidelines proposed by Ajzen (2006), for which six items related to energy and energy consumption were selected and paired with five-point scale semantic differentials, for the assessment of the emotional dimension of attitudes. The use of these guidelines has been validated in a variety of fields to measure attitudes. Additionally, to assess the cognitive dimension of attitudes, willingness to change consumption behaviours was also included in the attitudes section ("I am willing to change a particular behaviour that I do at home in order to be more sustainable.").

Affordances are elements that the environment provides so that a person can perform an action. This section was the only section that was developed without other tools, by selecting from the housing literature elements that are related to psychosocial and physiological comfort. These were rated on a 5-point scale in which a high rating indicated high importance of the item to be an affordance for comfort.

Health was a tool unaltered from the OFFICAIR questionnaire by (P. M. Bluyssen et al., 2015). Health was included since it not only is related to general comfort, but also because the items composing the questionnaire are all related to stress, which is a determinant of one's health. This questionnaire was used since it is the most widely used for assessing health in the indoor environment, while also taking into account symptoms and stress.

3.2.3 Study design

In the 2016 Fall semester at the Delft University of Technology, the second year bachelor's students were requested to fill out the resulting questionnaire. There were 316 students enrolled in the course, and each one received the invitation link. This link was unique to the specific email address to which it was sent, therefore only valid for the original recipient. The protocol was as follows: the day when the questionnaire was distributed, students were introduced to it with a live announcement in their course. After receiving the email with a link to it, students had two weeks to complete the survey. One week before closure, a reminder email was sent. The introduction e-mail instructed the respondent about the purpose of the questionnaire, in addition to providing procedural information, such as reminder and closure dates, expected time to fill out (about 30 minutes), and possibility of pausing and resuming at a later time. When starting the questionnaire, a consent form was presented to the student, where they were assured that data would be confidential and only used for this project. Additionally, they were informed that skipping questions was possible if they felt uncomfortable answering them.

3.2.4 Data management and analysis

The questionnaire was developed with the Qualtrics® online platform. Data was downloaded for analysis as an SPSS® file. Before analysis, some cases in the database were removed, such as those that were not more than 80% complete, as well as two questionnaires answered by non-students – i.e. course coordinators or teachers.

3.2.5 Clustering

This study utilized the TwoStep cluster analysis approach. Although there are several clustering approaches, this method has traditionally been used in marketing, for customer segmentation, and gained recent popularity in health-related research, especially for the exploration of health behaviours, eating disorders, and alcoholism in the homeless, among others (Ambrosini et al., 2017; Dietrich, Schuster, & Connor, 2014; Fleury, Grenier, & Bamvita, 2015; Pugh & Waller, 2017; Zaretzky, Flatau, Spicer, Conroy, & Burns, 2017). The advantage of the TwoStep analysis over other types of clustering approaches is that it allows for the segmentation of both categorical and continuous variables in a simultaneous manner, allowing for a minimal degree of data preparation and handling for the analysis. Therefore, it enables analysing demographic, health, psychographic, and behavioural data– which is of relevance in the present questionnaire (Norušis, 2012).

The TwoStep analysis was performed as indicated by Norušis (2012) using IBM SPSS Statistics 23. The technique is performed as follows: first, grouping the cases into pre-clusters and subsequently, the pre-clusters are administered a regular hierarchical clustering. As a result, an assortment of solutions with different number of clusters is produced. When a final cluster solution is achieved, it is necessary to validate the model with four steps. First, the silhouette measure of cohesion of the clusters model is recommended to be above 0.0 and preferably 0.2, to ensure validity of both within-cluster and between-cluster distances. Second, Chi2 tests and t-tests are performed with categorical and continuous variables respectively: all variables in the solution need to be statistically significant ($p<0.05$), this is done iteratively, removing non-significant variables until reaching the final model in which all variables are statistically significant. Third, it is recommended that variables of the final solution have a higher prediction score than 0.02; thus removing any variable below it. Finally, the database is randomly split into two, and the final solution model is applied to each of the halves, for which the solutions must be similar (Norušis, 2012; Tkaczynski, 2017).

3.3 Results

3.3.1 General characteristics of respondents & Participation rate

316 invitations were sent out to the students enrolled in the course “Technology 4 Construction and Climate Design”, of which 245 attended actively the course. A total of 223 completed the questionnaire, thus the response rate was 91.0%. The mean (SD) age was 20.3 (2.2) years, with ages ranging from 18 to 30.

3.3.2 TwoStep Cluster analysis and Validation

A TwoStep cluster analysis was performed initially by utilizing the original 65 variables, belonging solely to the behavioural constructs (emotions, attitudes, control, habits, and affordances), since the clusters have to be based on the behavioural expressions of homeostasis. Therefore, variables pertaining to demographics and health were not used to produce clusters. The TwoStep cluster analysis produced a final solution of six clusters, with 25 segmentation variables, with 193 respondents: 30 respondents were automatically excluded from the analysis by the TwoStep Cluster process, due to missing data. The size of the smallest cluster is 19 respondents (9.8%) and the largest being 49 (25.4%) (Figure 3.1).

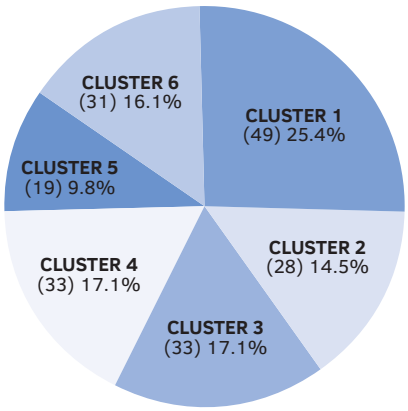


FIG. 3.1 Cluster Sizes: (respondents) Percentage.

TOC

The final solution presents a silhouette measure of cohesion and separation of 0.2, this score ensures that the within- and between-cluster distance is valid amongst the 25 variables, indicating variation between variables. Comparison of means analyses ensured that the final 25 variables were statistically significant, and hence they varied between clusters. Additionally, the variable with the lowest score for predictor importance was found to have a rating of 0.09, well above the recommended 0.02. Finally, randomly splitting the database into two, rendered comparable results in terms of the final solution, with minor changes determined (Table 3.3).

Descriptive statistics were produced from every variable, as frequencies, percentages, minimum and maximum, quartiles, mean, and standard deviation. Based on the descriptive results, as shown in Figure 3.2,, the most salient characteristics of each of the groups were used to name the groups –henceforth referred to as archetypes. Archetype 1: “Relaxed Optimists”; Archetype 2: “Unconcerned Indifferents”; Archetype 3: “Restrained Sensitives”; Archetype 4: “Positive Absolutists”; Archetype 5: “Incautious Negativistics”; Archetype 6: “Resigned Savers”.

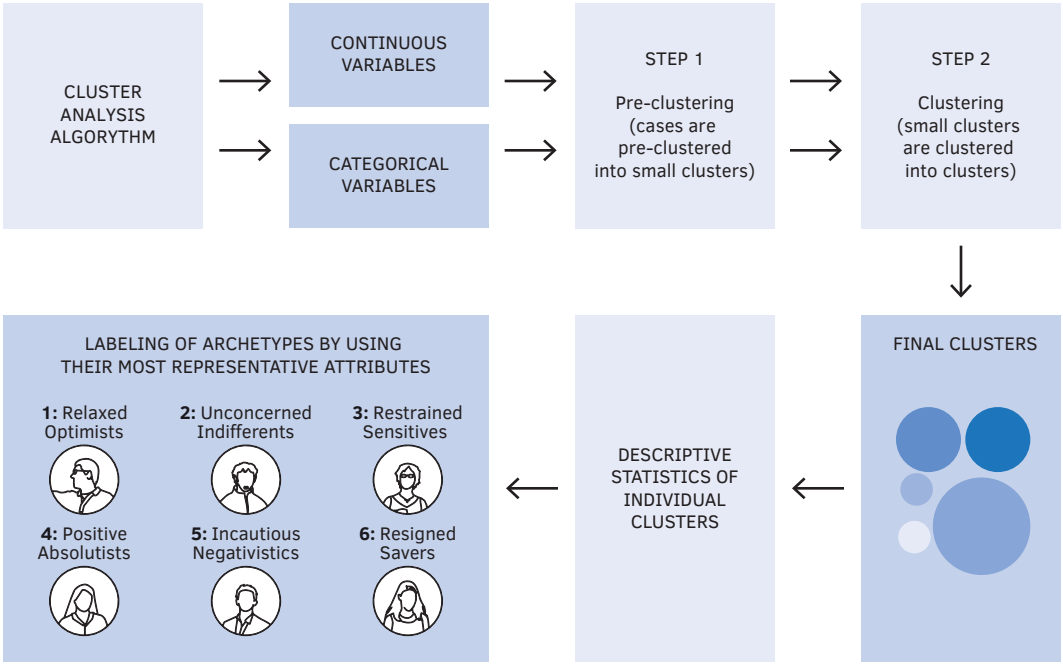


FIG. 3.2 Flow diagram of process from Two Step Cluster Analysis to Archetype naming.

TOC

TABLE 3.3 Final Solution variables and predictor importance

Predictor Importance	Final solution	First half solution	Second half solution
0.8-1.0	– Satisfaction (1.00) – Joy (0.92) – Fascination (0.87)	– Admiration (1.00) – Satisfaction (0.89) – Shame (0.88) – Dissatisfaction (0.88) – Internal control – freedom action (0.83)	– Satisfaction (1.00) – Joy (0.94) – Affordance- Safety (0.57)
0.6-0.79	– Admiration (0.74) – Affordance- Safety (0.69) – Pride (0.64)	– Joy (0.73) – Attitudes – water heating (0.69) – Affordance – Freedom of expression (0.69) – Internal control – Personalization (0.61) – Pride (0.60)	
0.4-0.59	– Affordance – Control (0.58) – Affordance – freedom of expression (0.53) – Dissatisfaction (0.40) – External control – climate (0.40) – Disgust (0.40) – Internal control – freedom action (0.40)	– Boredom (0.59) – Affordance – Spatial quality (0.57) – External control – Climate (0.48) – Affordance – Cleanliness (0.46) – Disgust (0.43) – Attitudes – behaviour change (0.40)	– Affordance- Safety (0.57) – Affordance – freedom of expression (0.57) – Disgust (0.53) – Fascination (0.47) – Pride (0.45) – Admiration (0.44) – Attitudes – behaviour change (0.41)
0.2-0.39	– Shame (0.33) – Affordance – Air quality (0.30) – Internal control – Relaxation (0.29) – Affordance – cleanliness (0.27) – Affordance – lighting quality (0.24) – Boredom (0.20)	– Affordance – Control (0.36) – Internal control – Relaxation (0.33) – Affordance – light quality (0.32) – Affordance – air quality (0.22) – Fascination (0.22)	– Internal control – freedom of action (0.37) – Affordance – lighting quality (0.36) – Boredom (0.32) – Affordance – cleanliness (0.30) – External control – climate (0.27) – Affordance – Control (0.27) – Internal control – Personalization (0.25) – Internal control – climate (0.21) – Internal control – Relaxation (0.20) – Dissatisfaction (0.20)
0.00-0.19	– Internal control – Personalization (0.19) – Affordances – spatial (0.18) – Attitudes – Behaviour change (0.16) – Habits – Personalize the place (0.14) – Attitudes – water heating (0.13) – Habits – warm up (0.10) – Internal control – Climate (0.09)	– Habits- warm up (0.18) – Habits – personalize the place (0.06) – Internal control – Climate (0.04)	– Attitudes – water heating (0.15) – Habits – personalize the place (0.11) – Affordance – Air quality (0.07) – Shame (0.04) – Habits- warm up (0.02)

Table 3.3 shows the final solution of the full database, in addition to the solutions of the database when split in halves. The predictor importance indicates the importance of variables predicating the model. It is suggested that variables with a low rating (0.02 or lower) should be avoided in the final solution. In addition comparison of the two halves with the final model shows relative minor changes in the importance of variables, thereby suggesting the variables of the final solution to be appropriate for the model.

3.3.3 Description of identified Archetypes

In this study, the definition of an archetype is the representation of a home occupant segment that embodies the most salient attitudinal, emotional, and behavioural responses of that specific segment to the home environment and energy use. In traditional archetype studies, it is proposed that members of each archetype share similar subconscious cognitive processes. These processes influence the members of a segment -in this case the home occupants- to respond in similar ways to certain stimuli of their environment (Hogg & Reid, 2006).

In the following tables, (Table 3.4 to Table 3.10) the descriptive results of the individual clusters are presented.

TABLE 3.4 General Characteristics

Characteristics	Total n (%)	C1 – 25.4%	C2 - 14.5%	C3 - 17.1%	C4 - 17.1%	C5 - 9.8%	C6 - 16.1%
Personal							
Gender							
Men	115 (51.8)	24 (49.0)	18 (64.3)	17 (51.5)	18 (56.3)	9 (47.4)	16 (51.6)
Women	107 (48.2)	25 (51.0)	10 (35.7)	16 (48.5)	14 (43.8)	10 (52.6)	15 (48.4)
Age (years)							
Mean (SD)	20.3 (2.2)	20.6 (2.4)	20.1 (1.2)	21.1 (3.3)	20.0 (2.0)	20.9 (2.4)	19.9 (1.4)
Highest education level							
Primary or Secondary school	179 (80.3)	40 (81.6)	22 (78.6)	28 (84.8)	26 (78.8)	14 (73.7)	22 (71.0)
Some college	6 (2.7)	1 (2.0)	0 (0.0)	2 (6.1)	0 (0.0)	1 (5.3)	1 (3.2)
Completed Bachelors	6 (2.7)	1 (2.0)	1 (3.6)	2 (6.1)	1 (3.0)	0 (0.0)	1 (3.2)
Completed Masters	32 (14.3)	7 (14.3)	5 (17.9)	1 (3.0)	6 (18.2)	4 (21.1)	7 (22.6)
Doctorate	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Nationality							
Dutch	210 (94.2)	48 (98.0)	27 (96.4)	28 (84.8)	31 (93.9)	17 (89.5)	31 (100.0)
Greek	3 (1.3)	1 (2.0)	0	2 (6.1)	0	0	0
Turkish	2 (0.9)	0	0	1 (3.0)	0	1 (5.3)	0
Others	8 (3.6)	0	1 (3.6)	2 (6.1)	2 (6.1)	1 (5.3)	0
Interested in a follow-up							
Yes	71 (31.8)	14 (28.6)	5 (17.9)	11 (33.3)	12 (36.4)	7 (36.8)	14 (45.2)
No	152 (68.2)	35 (71.4)	23 (82.1)	22 (66.7)	21 (63.6)	12 (63.2)	17 (54.8)

>>>

TABLE 3.4 General Characteristics

Characteristics	Total n (%)	C1 – 25.4%	C2 - 14.5%	C3 - 17.1%	C4 - 17.1%	C5 - 9.8%	C6 - 16.1%
Location of home							
Delft	151(67.7)	33 (67.3)	15 (53.6)	24 (72.7)	20 (60.6)	12 (63.2)	25 (80.6)
Amsterdam	11 (4.9)	2 (4.1)	1 (3.6)	3 (9.1)	2 (6.1)	1 (5.3)	1 (3.2)
The Hague	7 (3.1)	2 (4.1)	1 (3.6)	1 (3.0)	1 (3.0)	0	2 (6.5)
Rotterdam	4 (1.8)	2 (4.1)	1 (3.6)	0	0	0	0
Zoetermeer	4 (1.8)	1 (2.0)	1 (3.6)	0	1 (3.0)	1 (5.3)	0
Other	50 (22.4)	9 (18.0)	9 (32.4)	5 (15.0)	9 (18.0)	5 (26.5)	3 (3.6)
Building Variables							
Building type							
Apartment	55 (24.7)	14 (28.6)	5 (17.9)	9 (27.3)	7 (21.2)	5 (26.3)	6 (19.4)
Gallery apartment (with main door in a common external corridor)	41 (18.4)	9 (18.4)	7 (25.0)	6 (18.2)	5 (15.2)	5 (26.3)	5 (16.1)
Row house (with shared side walls)	84 (37.7)	20 (40.8)	10 (35.7)	10 (30.3)	16 (48.5)	6 (31.6)	12 (38.7)
Semidetached house (sharing one common wall)	7 (3.1)	2 (4.1)	1 (3.6)	1 (3.0)	2 (6.1)	0 (0.0)	1 (3.2)
Detached house (free-standing)	18 (8.1)	2 (4.1)	4 (14.3)	4 (12.1)	2 (6.1)	0 (0.0)	1 (3.2)
Other*	18 (8.1)	2 (4.1)	1 (3.6)	3 (9.1)	1 (3.0)	3 (15.8)	6 (19.4)
Occupants							
Number of people living in same house							
Over age of 18 – mean (SD)	5.6 (4.6)	5.6 (4.3)	5.3 (4.0)	4.8 (2.8)	5.8 (6.1)	5.1 (3.8)	7.6 (6.6)
Under age of 18 – mean (SD)	0.7 (1.0)	1.1 (0.9)	0.7 (0.8)	0.2 (0.4)	0.9 (1.0)	1.0 (0.7)	0.3 (0.5)
Type of occupant							
Family members	53 (23.8)	14 (28.6)	10 (35.7)	6 (18.2)	10 (30.3)	5 (26.3)	3 (9.7)
Housemates	148 (66.4)	30 (61.2)	18 (64.3)	25 (75.8)	20 (60.6)	11 (57.9)	23 (74.2)
(Un)married couple	10 (4.5)	2 (4.1)	0	2 (6.1)	1 (3.0)	1 (5.3)	3 (9.7)
Alone	12 (5.4)	3 (6.1)	0	0	2 (6.1)	2 (10.5)	2 (6.5)
Tenure							
Owner	38 (17.1)	10 (20.8)	6 (21.4)	4 (12.1)	10 (30.3)	4 (21.1)	2 (6.5)
Renter	184 (82.9)	38 (79.2)	22 (78.6)	29 (87.9)	23 (69.7)	15 (78.9)	29 (93.5)
Time residing in the house							
Less than 6 months	48 (21.5)	10 (20.4)	3 (10.7)	8 (24.2)	12 (36.4)	1 (5.3)	7 (22.6)
6 to 12 months	47 (21.1)	8 (16.3)	5 (17.9)	6 (18.2)	7 (21.2)	2 (10.5)	8 (25.8)
1 - 5 years	84 (37.7)	20 (40.8)	12 (42.9)	14 (42.4)	5 (15.2)	11 (57.9)	14 (45.2)
More than 5 years	44 (19.7)	11 (22.4)	8 (28.6)	5 (15.2)	9 (27.3)	5 (26.3)	2 (6.5)

* *8 respondents specified "Student housing" which is not a building type.*

TABLE 3.5 Health and Symptoms

Health in the last 12 months	N (%)	C1	C2	C3	C4	C5	C6
Asthma	15 (6.7)	2 (4.1)	3 (10.7)	1 (3.0)	1 (3.0)	3 (15.8)	3 (9.7)
Bronchitis/bronchial pneumonia	12 (5.8)	4 (8.2)	2 (7.1)	0 (0.0)	2 (6.1)	1 (5.3)	3 (9.7)
Wheezing or whistling in the chest	21 (9.5)	4 (8.2)	3 (11.1)	3 (9.1)	3 (9.1)	3 (15.8)	3 (9.7)
Other chest condition	10 (4.5)	1 (2.0)	0 (0.0)	3 (9.1)	3 (9.1)	1 (5.3)	0 (0.0)
Hay fever	61 (27.6)	12 (24.5)	4 (14.8)	0 (0.0)	10 (30.3)	8 (42.1)	14 (45.2)
Allergic rhinitis	96 (43.0)	22 (44.9)	10 (35.7)	14 (42.4)	15 (45.5)	11 (57.9)	17 (54.8)
Eczema	37 (16.7)	6 (12.2)	5 (18.5)	5 (15.2)	5 (15.2)	2 (10.5)	11 (35.5)
Dermatitis	6 (2.7)	3 (6.1)	0 (0.0)	1 (3.0)	0 (0.0)	2 (10.5)	0 (0.0)
Other skin conditions	30 (13.5)	7 (14.3)	5 (18.5)	3 (9.1)	4 (12.1)	4 (21.1)	3 (9.7)
High lipids in the blood	1 (0.5)	1 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Diabetes	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.2)
High blood pressure	3 (1.4)	3 (6.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Heart conditions	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.0)	0 (0.0)	0 (0.0)
Migraine	28 (12.6)	7 (14.3)	2 (7.4)	4 (12.1)	9 (27.3)	1 (5.3)	2 (6.5)
Depression	24 (10.8)	3 (6.1)	3 (11.1)	6 (18.2)	4 (12.1)	5 (26.3)	3 (9.7)
Anxiety	37 (16.7)	10 (20.4)	3 (11.1)	7 (21.2)	5 (15.2)	6 (31.6)	3 (9.7)
Psychiatric problems	13 (5.9)	3 (6.1)	2 (7.1)	3 (9.1)	1 (3.0)	4 (21.1)	0 (0.0)
Other problems	35 (15.8)	6 (12.2)	2 (7.4)	10 (30.3)	3 (9.1)	5 (26.3)	4 (12.9)
Symptoms while at home - At least once every 2-3 weeks, Related to indoor environment (yes and partly)							
Dry Eyes	36 (7.4)	6 (4.5)	3 (3.6)	8 (18.2)	3 (3.3)	7 (26.0)	6 (8.0)
Itchy or watery eyes	21 (4.8)	1 (1.2)	2 (2.0)	5 (8.5)	3 (4.0)	5 (12.2)	5 (12.5)
Blocked nose	57 (20.0)	11 (15.5)	5 (16.0)	9 (23.0)	7 (17.0)	7 (32.0)	10 (29.3)
Runny nose	40 (13.4)	6 (8.0)	5 (15.7)	6 (12.9)	6 (14.5)	5 (20.4)	6 (16.2)
Sneezing	59 (22.7)	13 (22.9)	4 (11.3)	6 (15.0)	10 (23.5)	9 (49.4)	10 (31.0)
Dry throat	37 (10.4)	10 (13.9)	1 (1.6)	3 (5.3)	8 (14.1)	6 (27.1)	5 (13.0)
Lethargy	25 (9.4)	6 (11.4)	2 (5.2)	5 (12.0)	2 (4.5)	5 (27.7)	3 (8.0)
Headaches	17 (5.6)	3 (4.3)	3 (9.5)	0 (0.0)	1 (2.0)	4 (18.5)	3 (7.2)
Dry, itchy, irritated skin	24 (5.3)	4 (4.2)	3 (5.3)	6 (7.4)	2 (2.4)	4 (16.6)	1 (1.5)
Breathing difficulty	11 (1.1)	1 (0.3)	1 (0.7)	1 (0.8)	1 (0.8)	3 (5.5)	3 (1.5)
Other symptoms	4 (0.1)	0 (0.0)	1 (0.3)	0 (0.0)	1 (0.3)	0 (0.0)	1 (0.7)

TABLE 3.6 Emotions towards the home

Emotions towards your home	Total	C1	C2	C3	C4	C5	C6
mean (SD) / 1: I don't feel this at all – 5: I feel this strongly							
Positive emotions							
Desire	3.2 (1.1)	3.2 (1.2)	3.1 (1.0)	3.2 (1.0)	3.2 (1.2)	3.1 (1.1)	3.4 (1.0)
Satisfaction*	3.6 (0.9)	3.9 (0.6)	4.0 (0.5)	2.7 (0.7)	4.2 (0.6)	2.2 (0.8)	4.1 (0.7)
Pride*	3.3 (1.2)	3.3 (1.0)	3.1 (1.1)	2.5 (1.3)	4.2 (0.7)	2.0 (1.0)	4.1 (0.7)
Hope	2.8 (1.2)	2.5 (1.1)	2.4 (1.1)	2.8 (1.2)	3.2 (1.1)	2.6 (1.3)	3.0 (1.0)
Joy*	3.7 (0.9)	4.0 (0.4)	3.4 (0.8)	2.9 (0.9)	4.1 (0.4)	2.5 (1.1)	4.3 (0.5)
Fascination*	2.7 (1.2)	2.2 (0.9)	2.3 (1.0)	1.9 (0.9)	3.9 (0.7)	2.1 (1.2)	3.7 (1.1)
Admiration*	2.5 (1.2)	2.1 (0.9)	1.9 (0.9)	1.9 (1.1)	3.6 (0.8)	2.0 (0.9)	3.6 (1.0)
Negative emotions							
Disgust*	1.8 (1.0)	1.3 (0.6)	1.4 (0.6)	2.0 (1.1)	1.7 (0.8)	2.9 (1.3)	2.1 (1.2)
Dissatisfaction*	2.1 (1.2)	1.6 (0.8)	1.9 (1.1)	2.5 (1.1)	1.7 (1.0)	3.4 (1.5)	2.0 (1.0)
Shame*	1.6 (0.9)	1.2 (0.5)	1.4 (0.6)	1.4 (0.7)	1.6 (0.8)	2.6 (1.3)	1.8 (1.2)
Fear	1.4 (0.8)	1.2 (0.5)	1.1 (0.5)	1.6 (1.1)	1.6 (0.8)	1.8 (1.1)	1.5 (0.9)
Sadness	1.4 (0.9)	1.1 (0.4)	1.2 (0.5)	1.7 (0.8)	1.4 (0.7)	2.0 (1.3)	1.6 (1.0)
Boredom*	2.0 (1.1)	1.7 (0.7)	1.7 (0.7)	2.5 (1.4)	1.9 (1.0)	2.7 (1.2)	1.9 (1.2)
Contempt	1.4 (0.7)	1.1 (0.5)	1.1 (0.4)	1.7 (1.0)	1.5 (0.7)	1.8 (0.9)	1.4 (0.7)

* *Variables predicting final solution ($p<0.001$)*

TABLE 3.7 Affordances: Elements of the home environment necessary to achieve comfort.

Environmental Affordances							
mean (SD) / 1: I don't need it to feel comfortable – 5: Very important for my comfort							
Adequate temperature	3.6 (0.9)	3.6 (1.0)	3.3 (1.1)	3.7 (0.9)	3.8 (0.5)	3.1 (0.9)	3.6 (0.9)
Air freshness*	3.9 (0.8)	4.1 (0.7)	3.5 (0.8)	4.2 (0.8)	4.2 (0.5)	3.5 (1.1)	3.6 (0.7)
Acoustical quality	3.2 (1.0)	3.2 (1.2)	3.3 (0.8)	3.3 (1.1)	3.6 (0.8)	2.9 (1.1	2.9 (0.9)
Lighting quality*	3.5 (0.8)	3.6 (0.7)	3.3 (0.7)	3.8 (0.9)	4.0 (0.5)	3.1 (0.9)	3.3 (0.7)
Freedom of interaction	3.7 (0.9)	3.8 (0.8)	3.4 (0.7)	3.8 (1.1)	4.1 (0.5)	3.7 (1.0)	3.6 (0.9)
Control of systems*	3.1 (1.0)	3.2 (0.9)	2.9 (0.8)	3.2 (1.1)	4.2 (0.4)	2.8 (1.1)	2.6 (0.9)
Freedom of being*	3.8 (0.9)	4.0 (0.6)	3.0 (0.6)	2.8 (1.1)	4.4 (0.4)	3.7 (0.8)	3.7 (1.0)
Privacy*	4.0 (0.9)	4.2 (0.8)	3.2 (0.8)	4.3 (0.7)	4.5 (0.5)	3.2 (0.9)	3.7 (0.8)
Spatial quality (layout and size)*	3.6 (0.9)	3.8 (0.7)	3.1 (0.8)	3.8 (0.8)	4.0 (0.7)	3.2 (1.2)	3.4 (1.0)
Cleanliness and orderliness*	3.5 (1.0)	3.6 (0.8)	3.1 (0.8)	3.7 (1.1)	4.0 (0.8)	2.7 (0.8)	3.1 (1.1)

* Variables predicting final solution ($p<0.001$)

TABLE 3.8 Locus of Control

Control	Total	C1	C2	C3	C4	C5	C6
mean (SD) / 1: Strongly disagree – 5: Strongly agree.							
Internal control							
Freedom of action*: I am able to do everything I want in my home, in accordance to my personal ideas.	3.5 (1.0)	3.6 (1.0)	3.8 (0.7)	3.0 (0.9)	4.2 (0.7)	2.6 (1.1)	3.5 (0.9)
Privacy: The feeling of privacy in my home is entirely determined by myself.	2.9 (1.0)	2.9 (1.1)	2.8 (0.8)	2.9 (1.0)	3.2 (1.1)	2.6 (1.1)	2.8 (1.1)
Spatial: Regardless of the size of my home, I can make myself comfortable there.	3.9 (0.9)	4.1 (0.9)	3.7 (0.9)	3.7 (0.9)	3.9 (0.9)	3.6 (0.8)	3.7 (0.9)
Order and cleanliness: It is up to me whether my home environment is kept in a tidy and clean state.	3.9 (0.9)	4.2 (0.8)	3.9 (0.9)	3.9 (0.8)	3.8 (0.9)	3.6 (1.1)	3.7 (1.0)
Climate*: I carefully control the temperature of my home to keep me comfortable.	2.7 (1.1)	2.2 (1.0)	3.1 (0.9)	2.7 (1.2)	2.9 (1.3)	2.7 (1.0)	2.8 (1.1)
Relaxation*: I am able to de-stress at home whenever I want.	3.5 (1.0)	3.7 (1.0)	3.6 (0.7)	3.1 (1.0)	4.0 (0.7)	2.6 (0.9)	3.4 (0.9)
Atmosphere: It is up to me whether or not I make the atmosphere I want in my home.	3.6 (0.9)	3.7 (0.9)	3.4 (0.8)	3.6 (1.0)	3.8 (0.8)	3.1 (1.1)	3.5 (0.9)
Personalization*: The way my home looks and feels reflects my personality.	3.4 (0.9)	3.5 (0.8)	3.4 (0.8)	3.2 (0.8)	3.8 (1.0)	3.1 (1.1)	3.5 (1.0)
Mood: I make an effort to get the right mood in my home.	3.6 (0.9)	3.6 (0.9)	3.4 (0.9)	3.5 (1.0)	4.1 (0.6)	3.7 (0.9)	3.5 (0.9)

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TABLE 3.8 Locus of Control

Control	Total	C1	C2	C3	C4	C5	C6
External control							
Freedom of action: To a great extent, I do not plan the actions and activities that I carry out in my home.	3.1 (1.0)	3.2 (1.1)	3.2 (1.0)	3.3 (1.0)	2.9 (1.0)	3.5 (0.9)	3.1 (0.9)
Privacy: Whether or not my home offers me the sense of privacy depends on fortunate circumstances.	2.7 (0.9)	2.6 (0.9)	2.6 (0.7)	2.7 (1.0)	2.8 (1.0)	2.6 (0.8)	2.8 (0.9)
Spatial: Feeling comfortable in my home is a matter of the layout and size of my house.	2.9 (1.0)	2.9 (1.0)	2.9 (0.8)	2.9 (1.0)	2.8 (0.8)	2.6 (1.1)	3.0 (1.0)
Order and cleanliness: I can't completely control the cleanliness of my home: they are the result of time.	2.9 (1.0)	3.0 (1.0)	2.8 (0.9)	3.1 (0.8)	2.9 (1.2)	3.5 (1.0)	2.7 (1.1)
Climate*: The temperature in my home is pretty much determined by the house itself.	3.2 (0.9)	3.3 (0.9)	2.9 (0.5)	3.4 (1.1)	2.8 (0.8)	2.7 (1.1)	3.7 (0.9)
Relaxation: Having a stress-free environment in my home is all luck: I cannot influence it.	2.5 (1.0)	2.3 (1.0)	2.5 (1.0)	2.8 (1.2)	2.5 (1.1)	2.5 (0.8)	2.7 (0.9)
Atmosphere: The atmosphere in my home is the way it is, without me doing anything about it.	2.7 (0.9)	2.8 (0.8)	2.7 (0.7)	2.7 (0.9)	2.4 (1.0)	2.5 (1.1)	3.1 (0.9)
Personalization: It is only a coincidence whether my home seems to reflect my personality or not.	2.3 (1.0)	2.3 (1.0)	2.4 (1.0)	2.5 (1.2)	2.3 (1.1)	2.4 (1.2)	2.4 (1.1)
Mood: The mood of my home is something that just happens by itself.	3.1 (1.0)	3.2 (0.9)	2.3 (0.7)	3.0 (0.9)	3.2 (1.1)	2.5 (0.9)	3.1 (1.1)

* *Variables predicting final solution ($p<0.001$)*

TABLE 3.9 Attitudes towards energy and energy consumption

Attitudes towards energy	Total	C1	C2	C3	C4	C5	C6
mean (SD)							
Behavioural intentions							
1: Definitely yes – 5: Definitely not							
Willingness to change behaviour to use less energy*	2.2 (0.9)	2.1 (0.9)	2.5 (0.7)	2.4 (1.0)	1.8 (0.6)	2.5 (1.1)	2.2 (0.9)
Willingness to live with less comfort to save energy	3.1 (1.0)	3.1 (1.0)	3.0 (1.0)	3.2 (1.0)	3.2 (0.8)	3.2 (11)	2.9 (0.9)
Social comparison attitudes towards energy use							
1: much more than others – 5: much less than others							
Space heating	3.4 (1.0)	3.4 (1.1)	3.8 (1.1)	3.3 (1.1)	3.6 (1.0)	3.3 (1.1)	3.4 (0.9)
Water heating*	2.9 (0.7)	2.9 (0.9)	3.2 (0.5)	2.9 (0.7)	2.7 (0.7)	3.0 (0.9)	3.1 (0.8)
Use of energy-consuming products	3.0 (0.7)	2.9 (0.9)	2.8 (0.7)	3.1 (0.7)	3.0 (0.8)	2.7 (0.7)	3.1 (0.8)
Actual expenditure knowledge							
Yes, I know – n (%)							
Electricity	6 (2.7)	1 (2.0)	1 (3.6)	1 (3.0)	1 (3.0)	1 (5.3)	0 (0.0)
Gas	8 (3.6)	1 (2.0)	1 (3.6)	2 (6.1)	1 (3.0)	1 (5.3)	1 (3.2)

* *Variables predicting final solution (p<0.001)*

TABLE 3.10 Habits

	Total	C1	C2	C3	C4	C5	C6
Yes, I use energy for behaviour X – n (%)							
Relax	63 (28.3)	15 (30.6)	7 (25.0)	8 (24.2)	10 (30.3)	8 (42.1)	7 (22.6)
Warm up*	163 (73.1)	30 (61.2)	16 (57.1)	29 (87.9)	25 (75.8)	15 (78.9)	28 (90.3)
Clean up	104 (46.6)	25 (51.0)	13 (46.4)	15 (45.5)	18 (54.5)	9 (47.4)	9 (29.0)
Personalize the place	22 (9.9)	5 (10.2)	3 (10.7)	4 (12.1)	4 (12.1)	3 (15.8)	1 (3.2)
Socialize in person	52 (23.3)	12 (24.5)	5 (17.9)	7 (21.2)	9 (27.3)	9 (47.4)	5 (16.1)
Socialize online	117 (52.5)	29 (59.2)	17 (60.7)	14 (42.4)	18 (54.5)	13 (68.4)	19 (61.3)
Freshen up	142 (63.7)	34 (69.4)	19 (67.9)	18 (54.5)	26 (78.8)	10 (52.6)	21 (67.7)
Feel privacy	26 (11.7)	5 (10.2)	4 (14.3)	5 (15.2)	4 (12.1)	3 (15.8)	2 (6.5)
Do my hobbies	61 (27.4)	14 (28.6)	9 (32.1)	10 (30.3)	8 (24.2)	9 (47.4)	7 (22.6)
Create a mood*	74 (33.2)	10 (20.4)	7 (25.0)	19 (57.6)	18 (54.5)	5 (26.3)	9 (29.0)
Cook	197 (88.3)	46 (93.9)	24 (85.7)	26 (78.8)	29 (87.9)	18 (94.7)	29 (93.5)

* *Variables predicting final solution (p<0.001)*

Archetype 1: Relaxed Optimists

General characteristics: The Relaxed Optimists (ROs), represents a quarter of the sample (n=49), they are balanced in terms of gender (51% women) and 32% reported to be interested in a follow up of the study. The ROs are the group with highest percentage of apartment occupiers (29%); however, most (41%) live in a row house, and 61% of them with on average 5.6 housemates.

Health status and symptoms: The ROs report the lowest rate for wheezing (8%) and depression (6%); but have the highest prevalence (8%) of hypertension or high blood lipids. They also report the lowest rates of different nasal-ocular as well as that of breathing difficulties (0.3%).

Emotions: As far as positive emotions are concerned, joy (4.0) and satisfaction (3.9) are high among ROs. For negative emotions, ROs feel them the lowest: disgust (1.3), dissatisfaction (1.6), shame (1.2), and boredom (1.7).

Affordances: ROs report privacy (4.2), air freshness (4.1); freedom of being (4.0), spatial quality (3.8) cleanliness and acoustical quality (3.6) as rather important for them to feel comfortable, with the least important affordance being having the possibility of controlling systems (3.2) (i.e. thermostats, shade controllers, etc.).

Control: ROs report low internal control for climate (3.2) representing the lowest for any group, while they also report the highest rates for controlling the indoor layout to achieve comfort (4.1) and that of cleaning and ordering (4.2). Relaxing (3.7), personalizing (3.5), and being free to do what they want (3.6) resulted in slightly above average ratings for ROs. For external control, relaxation is low (2.3), while the mood of their home is something they do not have to actively control to feel comfortable (3.2)

Attitudes: ROs are relatively willing to change their behaviours to save energy; however, they are more unwilling to give up comfort for the same end (3.1). Furthermore, they have the belief that they spend slightly less energy than others do.

Habits: ROs are the group that reports to spend least energy for changing or creating the mood (20%). Additionally, they are the second lowest group for energy expenditure for warming up habits (61%).

Archetype 2: Unconcerned Indifferents

General characteristics: The Unconcerned Indifferents (UI) is made of 28 respondents (14.5%) and has the highest proportion of men (64%). They are the least interested group in a follow-up of the present research (18%). It is the group that needs to commute the most, with 53% living where they study, they represent the lowest percentage of apartment occupiers (18%); 36% live in a row house, while also being the group that lives the most with family members (36%).

Health status and symptoms: UIs have the lowest rates in rhinitis (36%) and "other problems" (7%). They also report the lowest rates in sneezing (11%) and dry throat (2%).

Emotions: UIs seem to have in general moderate feelings, both negative and positive. They report the lowest in desire, hope, and admiration (3.1; 2.4; 1.9), while also having the lowest rating for boredom (1.7); however their dissatisfaction is low (1.9); while having a high satisfaction (4.0), but moderate pride (3.1), joy (3.4), and fascination (2.3).

Affordances: The UIs are generally unconcerned by the affordances offered by the home environment, they report the lowest rating for affordances of air freshness (3.5), privacy (3.2), and spatial quality (3.1), while also lower-than-average ratings for lighting quality (3.3), control of systems (2.9), cleanliness (3.1), and freedom of action (3.0).

Control: UIs report the highest internal control for their home climate (3.1). They also report higher than average internal control scores for freedom of action (3.8) and relaxation (3.6). In external control, they report no need for creating private spaces (2.6), being the lowest score for all groups; while showing lower-than-average score for external control of climate (2.9) – supporting their high score in the internal scale of this variable.

Attitudes: UIs have the strongest refusal for willingness to change their behaviour for saving energy (2.5), while having the second highest lack of will for giving up comfort (3.0). Additionally, they report the highest ratings in comparing themselves to others, with the belief that they spend much less energy for both space and water heating (3.8 and 3.2).

Habits: Only 57% of UIs report to spend energy for warming up, which is the lowest rate of all groups.

Archetype 3: Restrained Sensitives

General characteristics: The Restrained Sensitives (RS) is made of 33 respondents (17.1%) and has a balanced proportion of men and women (48.5%). 33% of them are interested in a follow-up of the study. The group is the oldest, with a mean age of 21.1. About 73% of them live in the same city where they study, and have the lowest rates of row-house occupiers (30.3%), while 27% live in an apartment. 76% live with housemates, however, they live with the lowest number thereof (4.8). Finally, they are the second largest renter group, with 88%.

Health status and symptoms: RSs score the lowest rates of prevalence in four diseases: asthma (3%), bronchitis (0.0%), hay fever (0.0%), and skin conditions (9.1%), making them in this regard, the healthiest group. Nevertheless, they do present the highest rate of 'other problems' (30%). However, in terms of symptoms, they present higher than average rates in dry and watery eyes (18% and 9%), as well as blocked nose and lethargy (23% and 12%).

Emotions: RSs have rather low positive emotions, scoring the lowest for both fascinations and admiration (1.9 both). With satisfaction (2.7), pride (2.5), and joy (2.9). On the other hand, their negative emotions result in higher than average scores: disgust (2.0), dissatisfaction (2.5), boredom (2.5), with the exception being shame (1.4).

Affordances: RS find sensorial affordances important for their comfort, namely air freshness (4.2), which is reported as highest of all groups, as well as lighting quality (3.8) and cleanliness (3.7) both having the second highest scores. As far as psychological affordances are concerned, they rate second highest with privacy, (4.3), spatial quality (3.8), and choice of control (3.2); however they score lowest with freedom of being (2.8).

Control: RSs report slightly lower than average rates in internal control, while slightly higher than average scores for external control. Thus, in internal control they report second lowest in freedom of action (3.0), climate (2.7), relaxation (3.1), and personalization (3.2). While for external, they score second highest for climate (3.4), and highest for relaxation and personalization (2.8; 2.5).

Attitudes: RSs show a very slight willingness to change behaviour to save comfort (2.4); this is however, the second highest score for unwillingness. Additionally, they score highest with willingness to give up comfort (3.2). Additionally, they report to spend slightly less than others on water heating (2.9).

Habits: RSs scored the smallest percentage in spending energy as a habit on online socializing (42%) as well las for cooking (79%), and the highest for creating the mood (57.6%), while for warming up, they represent the second highest group (88%).

Archetype 4: Positive Absolutists

General characteristics: The Positive Absolutists (PAs) is made of 33 respondents (17.1) and has a high proportion of men (56%). They are the second youngest group (20.0) and 61% of them live where they study, thus, being the second group that needs to commute the most. About half of them live in row houses and 60% of them with housemates. It is the group with fewer renters: 70%, while also having the largest proportion of occupants living less than 6 months in the home (36%).

Health status and symptoms: PAs is the second healthiest group, with only high rates of "other chest conditions" (9%) and migraine being well over the average (27%). Additionally, they have the lowest rates of lethargy and dry eyes (4.5% and 3%) in terms of symptoms.

Emotions: PA have strong positive emotions towards their home, reporting the highest ratings for satisfaction (4.2), pride (4.2), hope (3.2), fascination (3.9), and admiration (3.6), while also exhibiting relatively low negative emotions.

Affordances: PAs report the highest rating in every single affordance, be it sensorial or psychological, therefore, for them, sensorial and psychological aspects are of high importance to feel comfortable.

Control: PAs show high internal control and low external control. They score highest of all groups on internal control for freedom of action (4.2), privacy (3.2), relaxation (4.0), atmosphere (3.8), personalization (3.8), and mood (4.1).

Attitudes: PAs report the strongest intention for behavioural change to save energy (1.8), though they report the strongest refusal for giving up comfort (3.2). Additionally, they report the strongest conviction of spending more water heating than others (2.7).

Habits: 75.8% of PAs report to spend energy for warming up, while the group has the largest proportion of spenders for cleaning and (55%) and freshening up the home (79%).

Archetype 5: Incautious Negativistics

General characteristics: The Incautious Negativistics (IN) is made of 19 respondents (9.8%) and has the highest proportion of women (52.6%). About 37% report to be interested in a follow-up. 32% of them live in a row house, while they also have the highest percentage of gallery apartment inhabitants (26%). They are the group with smallest percentage living with housemates (58%) and the largest living alone (11%). 58% of them have lived between 1-5 years in their homes, representing the largest group for this period.

Health status and symptoms: INs is the group with largest prevalence of diseases. They rate highest in asthma, wheezing, rhinitis, skin conditions, high blood lipids, depression, anxiety, and 'other psychiatric problems'. They do rate with the lowest scores in migraine and eczema. Furthermore, they present the highest scores of all sorts of SBS symptoms, except for itchy eyes,

Emotions: INs present the highest scores in all negative emotions, and the lowest scores in all positive emotions, except for hope, fascination, and admiration. Therefore, they are the most emotionally negative group.

Affordances: INs report the lowest scores in importance for all sensorial affordances; and score lower than average in all psychological affordances.

Control: INs report the lowest ratings in internal control for all but two variables: climate and mood. For external control, they score the lowest scores in climate control options.

Attitudes: INs report the strongest refusal for willingness to change behaviours or to give up comfort (2.5 and 3.2). They also hold the stronger beliefs of being bigger spenders in terms of space heating, and appliance ownership (3.3 and 2.7).

Habits: For seven behaviours, INs represent the highest percentages of habitual energy expenditure, namely in relaxation, personalization, socializing online and in person, making privacy, doing hobbies, and cooking. They rate as the lowest spenders in freshening up (53%) while they are the third biggest spenders in warming up (79%).

Archetype 6: Resigned Savers

General characteristics: The Resigned Savers (RS) is made of 31 respondents (16.1%) and has a balanced ratio of men to women (48.4%). They represent the youngest group, with a mean age of 19.9, while showing the highest interest in a follow up, with 45%. RSs have the highest percentage of people living in the place where they study (81%). 39% live in a row house, while 19% in an apartment, and report the largest number of adult co-occupants 7.6. It is the group with the highest rate of renters (94%).

Health status and symptoms: RS is the group with the second largest prevalence of diseases. They rate highest in bronchitis (9.7%), hay fever (45%), eczema (36%), and diabetes (3%). They do rate lowest in dermatitis, anxiety, and psychiatric problems. As far as symptoms are concerned, they rate highest in itchy and watery eyes, and lowest in dry skin, with the rest of symptoms having slightly over the average rates.

Emotions: RSs present the highest scores in three positive emotions: desire (3.4), joy (4.3), and admiration (3.6), while reporting higher than average scores for other positive emotions. RFs also have a tendency to experience negative emotions slightly stronger above the global average.

Affordances: RSs report lower than average scores in both psychological and sensorial affordances, while scoring lowest in choice of control of systems (2.6) and acoustical affordances (2.9). The have the lowest scores in importance on all sensorial affordances, while scoring lower than average in all psychological affordances.

Control: RSs report low scores in internal control, and some of the highest scores in external control. They report highest in privacy, spatial, mood, atmosphere, and climate. However, they report the lowest score in external control for climate.

Attitudes: For willingness to change behaviour, RSs report an average score of 2.2. They are however, the group that reports the strongest score on willingness to give up comfort to save energy (2.9). This is congruent with their affordance ratings.

Habits: For six behaviours, RSs represent the lowest percentages of habitual energy expenditure, namely in relaxation, cleaning, personalizing, socializing in person, creating privacy, and doing hobbies. However, they rate highest on warming up with 90% of them needing to spend energy for it.

3.4 Discussion

3.4.1 General

This study sheds light on how the TwoStep cluster analysis can be used as an instrument taken from marketing, to identify homogenous groups, in order to assist energy engineers, architects, and designers. It is worth noting that the aim of understanding motivation of energy consuming behaviours through occupant profiles is to achieve energy reductions through improved interactions between occupant and technology, rather than total energy reduction.

In this study, variables pertaining to psychosocial and physiological homeostasis, from a perspective of behavioural constructs (emotions, attitudes, control, habits, and affordances) in a specific domain (home environment and energy expenditure), were used to produce six groups, with a model of 25 predicting variables. It is worthwhile to note that all the constructs chosen as important for understanding behaviour (emotions, attitudes, affordances, control, and habits) were represented with the 25 final predicting variables produced by the TwoStep analysis. This suggests that both constructs and items were adequately chosen and are of relevance for the categorization of occupants in this context.

The descriptive statistics of each segment yielded insights into the mental constructs of the segments and their motivations of their own behaviours, along with health data, and demographics, and a better understanding of the energy use habits of each of the segments. This sort of data is valuable for researchers as it enables the customization of offerings to the segments, for the improvement of their health, comfort, and energy savings. Therefore, tailored-made solutions can be developed for each archetype based on their characteristics. In this study, for example, Archetype 5, the Incautious Negativistics, report the highest incidence of health problems, which is paired with weak positive emotions, strong negative emotions, low internal control, and highest number of energy expending habits. Though no correlation analysis was performed in the present study, it is worth comparing those descriptive results with earlier research that has shown that students with higher levels of external locus of control also experience higher levels of stress and higher levels of illness (Roddenberry & Renk, 2010). Moreover, in other studies, it has been found that there is a tendency for students who had a recent negative event to have an increased tendency of rhinitis, while in a Finnish study; it was found

that rhinitis was increasingly manifested when students experienced stressful life events (Bluyssen et al., 2016; Kilpeläinen, Koskenvuo, Helenius, & Terho, 2002). It has also been shown that pessimistic people tend to have more cardiovascular diseases, stress, and ill-health, and in general, live shorter lives (Byrnes et al., 1998; Costanzo et al., 2004; Kiecolt-Glaser et al., 2002)[29-31]. Therefore, this archetype represents the greatest social challenge, and thus should be considered a 'high priority' segment, since their health and energy expenditure need be improved, while taking into account their negative attitudes towards energy, and their specific locus of control. This group in particular presents an opportunity for future research, to find out the reasons why they spend more energy and their ill-health, while also understanding what their particular motivations for change could be, based on their attitudes and control levels. This archetype requires a different approach to the Positive Absolutists, who have high positive emotions, a high need of environmental affordances, and high levels of internal control.

In many cases, simply attempting to make people use less energy or change certain behaviours may be insufficient. This is because, in simple terms, there are two systems in which behavioural constructs arise: reflective and automatic (Thaler, Sunstein, & Balz, 2014). Traditionally, trying to achieve behavioural changes has been tackled from the reflective perspective: influencing behaviour with the role of rationality, information, or technology, by providing rational information that a person should understand, by offering incentives, and the like. However, it has been shown that these strategies are abstracted from the contexts in which behaviours occur, and additionally, knowledge and information do not drive behaviour. Automatic processes, related to emotions, attitudes, needs or habits -constructs which result in behaviour- are generally unconscious, irrational, and emotional (Kelly & Barker, 2016). As a result, behaviour is a blurred combination of both processes and therefore solely focusing on one strategy has proved to be insufficient. Thus, 'archetype-tailored' intervention points of two types could be implemented: hard and soft. Hard solutions address the reflective system, and their goal is to affect behaviours through contextual solutions –i.e. customized appliances, system controls, (semi)automation, defaults, and persuasive design. Soft solutions address the automatic system, affecting behaviour through the influence of emotions, attitudes, and needs.

Each of the constructs studied in this study have to be tackled with the adequate strategy to influence it. For example, attitudes can be tackled mainly with automatic strategies. Attitudes seem to be formed by attributing valence to an object (Vogel & Wanke, 2016). Changing attitudes is therefore conditioned: if the object is linked to a positive valence, the attitudes towards it may be positive. Thus, to change attitudes, the individual needs to be exposed to the object while linking it to another object with

a positive valance. In such a way the first object becomes more favourable (Vogel & Wanke, 2016). The problem of energy is that energy tends to be 'invisible' for the average user; therefore changing attitudes towards it proposes a different challenge.

Similarly, locus of control is linked to the concept of self-efficacy: the former being the degree to which an individual believes to have control over a certain behaviour, while the latter being the perceived ease of performing such behaviour (Ajzen, 2002; Bandura, 1994; Stewart & De George-Walker, 2014). In this survey, self-efficacy was not assessed since the survey focuses on beliefs about control (locus of control) rather than about how well the person thinks they will perform in given situations (Bandura, 1994). Based on this, it can be deduced that there might be people who regard their comfort as 'personally determined' (high internal control) (i.e. Archetype 4), but who believe they lack the skills needed to carry out the behaviour (low self-efficacy) that would result in comfort, this type of people would therefore see activities to improve their comfort as ineffectual. Therefore, understanding these measures can help designers and energy engineers to offer "comfort and energy-tailored interventions" by adapting these interventions to the occupants' locus of control. This approach has been used in nursing to generate behavioural change amongst alcohol consumers by offering them customized programs based on their locus of control (Strecher, McEvoy DeVellis, Becker, & Rosenstock, 1986). Because previous research suggests that locus of control is learned and conditioned from the environment, the strategies for its change should focus on the reflective system.

Finally, emotions can be used as a driver to change attitudes, as previously mentioned. Provoking emotions can be also useful to change behaviour, since emotions have a large effect on decision making and the final behavioural expressions (Zajonc, 2000). Strategies for this construct should therefore focus on the automatic system.

It is worthwhile to mention that these archetypes are not representative of the population, and a study with an extended sample should be conducted. For designing such interventions, however, further studies are needed: interviews, observations, or focus groups and participatory design techniques.

3.4.2 Limitations and future research

A few important limitations restrict this study: firstly, a self-reporting technique for gathering data of behavioural constructs was used; a method that in future research will be supported by other data gathering techniques, such as interviews

and observations. Secondly, this sample is limited to bachelor students, which was comprised of people with similar background, age, and educational level, likely resulting in generalizing beyond such sample inaccurate. As a result, in future research the sample should be extended, to have final clusters that are more representative of the population. Thirdly, the TwoStep analysis excludes from the analysis any case with missing data; therefore, if the amount respondents who have missing data is too high, too many cases are eliminated from the final model. In the present study, 30 cases were excluded from the final clusters due to missing data. Finally, the TwoStep cluster analysis, although appropriate for this study, may be overly descriptive compared to other types of analysis, this might result in lower quality solutions without the capacity of predicting behaviour. With a larger sample, further studies can be carried out, such as interviews with representatives of each of the archetypes, observations of their behaviours at home and measurements of IEQ conditions, and focus groups to design and develop bespoke intervention points. Additionally, it would be valuable to perform further statistical analyses, such as correlations between health and emotions or health and locus of control.

3.5 Conclusions

To conclude, it can be said that the findings of this study show that the method of analysis seems to fit the purpose of this study, which is to provide evidence that the TwoStep cluster analysis method is an appropriate technique to use with the chosen constructs and items constituting the questionnaire. One of the reasons for this is because that particular method allows using both categorical and continuous variables, which compose the questionnaire. Furthermore, the final model of clusters comprised variables belonging to items of all the constructs, showing that the selection of such items was adequate for this questionnaire. With the six resulting archetypes, the study asserts that occupants may have different needs and motivations that culminate in behaviours. Although qualitative research is needed with the intent to understand the quantitative database at a deeper level, it can be concluded that certain constructs do vary enough from archetype to archetype, which means that the home environment of each archetype could be shaped around the main needs of the specific archetype so as to better support efficient behaviours and habits.

Finally, the results of this study are an invitation to produce further investigations with an expanded and varied sample. Hence, this study can be used as a stepping-stone to enlarge the sample and to produce archetypes that are more representative of the population. The results of that future research, in their turn, would enable the development of empirical studies to support the quantitative findings with qualitative ones.

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TOC



PART 3

Enhancement of Clusters with Interview Data + Building Features Data



4 Integrating qualitative and quantitative research to develop the final archetypes

Developing home occupant archetypes: First results of mixed-methods study to understand occupant comfort behaviours and energy use in homes

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Developing home occupant archetypes: first results of mixed-methods study to understand occupant comfort behaviours and energy use in homes

ABSTRACT To better understand home energy consumption, it is important to study the behaviours of occupants in their homes, especially in relation to their comfort needs. A mixed methods study comprising of a questionnaire, interviews, indoor environmental parameters monitoring, and energy consumption readings was performed to group home occupants based on their behavioural patterns. The TwoStep cluster analysis produced five clusters of home occupant with the data from 761 questionnaire respondents. The clustering model comprised of 28 variables including constructs of emotions, comfort affordances, and locus of control. Then, in-depth semi-structured interviews were conducted and IEQ monitoring and energy readings were taken with 15 of the questionnaire respondents. The results of the field study were used to substantiate the findings of the questionnaire. The combination of the statistical clusters with the data from the field study resulted in five archetypes: five distinct types of home occupants, differing in their behavioural motivations towards achieving comfort, and their use of energy when doing so. This study shows that a mixed methods approach is valuable for better understanding energy consumption and implementing archetype-customized lines of action to reduce energy use and maintain comfort.

KEYWORDS mixed methods, energy consumption, occupant behaviour

4.1 Introduction

Understanding behavioural patterns of occupants in their home -where they spend over 60% of their time- (Bonnefoy et al., 2004) seems to be essential to achieve reductions in energy consumption. This is because the actual energy consumption of dwellings is not only related to the building (technologies and performance), but also to the occupant (behaviours, lifestyle). These behavioural patterns need to be investigated from an occupant-centered perspective by taking into account factors such as comfort needs, satisfaction, perception, behaviour, physiology, culture, as well as attitudes, and socioeconomic status (Bluyssen, 2000; 2014b; Guerra-Santin et al., 2016; Indraganti & Rao, 2010; Karjalainen, 2007; Ortiz et al., 2017; K. C. Parsons, 2002). To ensure a reduction in energy consumption in the residential sector, both components –building and occupant- need to be assumed as an interacting system. Currently, a lack of knowledge is detected regarding 1- occupants' behaviours in their homes, 2- how they use energy, and 3- what their psycho-behavioural motivators when using energy are. This could be because traditionally in the indoor environmental quality (IEQ) field, these components are being researched independently from one another and unequally in terms of amount of studies.

As an example, between 1997 and 2015, only 13% of articles in energy research used qualitative methods. Contrarily, energy engineering (quantitative research) received 35 times more funding than behavioural and energy demand research (qualitative research) (Ortiz et al., 2017; Sovacool, 2014). In the last decades, trends suggest that research on the human dimension of energy use has increased (Hong, D'Oca, Turner, & Taylor-Lange, 2015), but they also show that interdisciplinarity is still uncommon. An example of qualitative methods in energy research is an investigation about owners' reasons to undertake home improvements, finding that their motivations were linked to the meaning of homes as a place for comfort and family life rather than as one for future investments (Munro & Leather, 2000). Similarly, user-centered methods were used to explore the behaviours and attitudes of owners towards home improvements; where five archetypes were developed based on interviews, claiming that the value of such an approach for tackling technical challenges is to enable the development of tailor-made strategies to suit each archetype to improve retrofit policies (Haines & Mitchell, 2014). Another study integrated the influential factors in domestic energy-saving behaviours in France, by using a survey that combined data from building and user characteristics. It showed a way in which energy behaviours can be included in the design of energy policies to encourage energy savings (Belaid &

Garcia, 2016). Mixed methods were also used in a study aimed at understanding how occupants create and maintain thermal comfort at home: environmental variables were recorded, occupants answered a survey about how they had achieved comfort, and they were interviewed about why and when such thermal comfort actions were performed (Tweed, Dixon, Hinton, & Bickerstaff, 2014). Those are examples of the use of mixed-methods to tackle technical challenges related to energy consumption. It must be noted that those studies tend to focus on the development of future policies and one-time home improvements or thermal comfort actions, and not on holistic comfort behaviours

Previous studies have already demonstrated that different behavioural patterns among occupiers lead to energy consumption discrepancies. A study from 2018 used principle component analysis to identify the behavioural patterns of Greek home occupants based on a questionnaire assessing building characteristics, occupant behaviour, and socio-demographic variables, in which they found six patterns (Vogiatzi et al., 2018). Similarly, in the same year, in a study by University of Cambridge researchers (Ben & Steemers, 2018) used a questionnaire and factor analysis to find five profiles based on the occupants' use of space heating. A Dutch survey found four lighting behavioural profiles that vary in their impact on consumption, household, and building characteristics (Bedir & Kara, 2017). A different approach was used in an Italian study in which they employed simulation and prediction, and the results proposed that occupant behaviours can be classified into three types of lifestyle that impact energy consumption in relation to thermal, ventilation, water, and lighting behaviours (Barthelmes, Becchio, & Corgnati, 2016). In Wales, a study segmented survey respondents based on their values, perceptions, and self-reported behaviours in regards to energy, and six occupant segments were identified (Guerra Santin, 2011; Poortinga & Darnton, 2016). Finally, a study in the Netherlands categorized home occupants based on heating behaviours and found five types of behavioural patterns (Guerra Santin, 2011). Further studies performed between the 1980s and the early 2010s intending to categorize types of occupants, have generally used statistical approaches, such as principal component analysis, discriminant analysis, cluster analysis, correlation analysis, exploratory factor analysis, or factor analysis (Hughes & Moreno, 2013; Sütterlin, Brunner, & Siegrist, 2011; W. F. Van Raaij & T. M. Verhallen, 1983).

In addition, other studies have suggested that different types of occupants influence differently the energy of their residences; and therefore, there is a need to better understand these behavioural differences -in addition to taking into account age, lifestyle and number of occupants (Motuziene & Vilutiene, 2013). One objective of finding patterns is to have more accurate performance predictions (Azar & Menassa, 2012; Daša Majcen, Laure Itard, & Henk Visscher, 2013; Menezes, Cripps,

Bouchlaghem, & Buswell, 2012). This is supported by D'Oca, Fabi, Corgnati, and Andersen (2014) who found that probabilistic profiles can help strengthening energy models. A reason for this is provided by a study suggesting that out of an average of 27 factors influencing space-heating behaviours, only a few tend to be considered in building performance simulations (Wei, Jones, & De Wilde, 2014). A similar conclusion was found in a study researching adaptive occupant behaviours by sorting them into three categories: observation, modelling, and simulation. It was concluded that with the appropriate variables, effects of behaviour on energy performance can be reduced (Gunay, O'Brien, & Beausoleil-Morrison, 2013). In low energy houses, it was found that occupants tend to feel more aware of energy and water consumption, especially due to the feedback, and this awareness triggered behavioural changes (Zalejska-Jonsson, 2012). Taking into account the aspects mentioned above, behaviours add considerable weight to the energy use and performance of buildings; estimated to affect by factors from 3 to 10 of residential energy use (Hong et al., 2016; Jia et al., 2017; Veselý & Zeiler, 2014).

Consequently, the results of the current literature in the energy engineering and the IEQ fields suggest that there are three needs. 1) Better understanding human behaviour in terms of energy use; 2) better interdisciplinary collaboration between the engineering and behavioural fields; and 3) better understanding the occupant component in the development and operation of buildings and its features.

This study goes beyond the statistical clustering of questionnaire respondents by incorporating qualitative data and building features data to the results. More specifically, this study is a development of the questionnaire performed by Ortiz and Bluyssen (2018). In that proof-of-concept, six archetypes were found by using a specialized questionnaire and the TwoStep cluster analysis. It was concluded that the use of the TwoStep technique is fitting for the variables used, as the questionnaire included categorical and continuous variables (Norušis, 2012). The authors suggested that substantiation of the archetypes was needed with the use of qualitative methods. Combining the results of the cluster analysis with those of qualitative data can strengthen the clusters into "archetypes" (Ajzen, 1991).

Therefore, the aim of the present study is to strengthen the statistical clusters, in order to formulate archetypes by substantiating the clusters with the mixed-methods data collected from the field study (interviews, IEQ factors, energy readings, and building features).

4.2 Methods

4.2.1 Study design

The study comprised of two parts. Figure 4.1 shows that in the first part of the study, a specialized questionnaire was administered to a sample of home occupants in the Netherlands and France. The second part was a field study in which qualitative data was collected by interviewing participants, and building data was also gathered with a building characteristics checklist, by monitoring indoor environmental parameters (temperature, humidity, and CO2), and by taking energy readings.

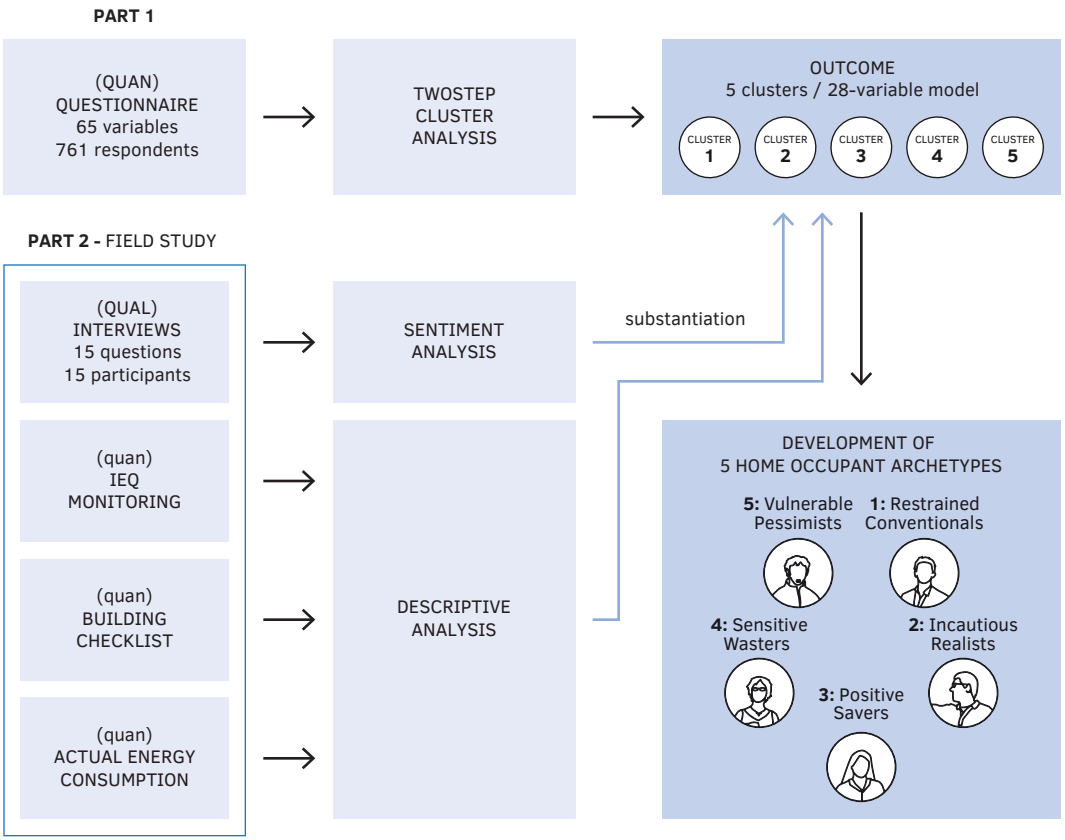


FIG. 4.1 Study design

TOC

The quantitative part involved a previously-developed questionnaire (Ortiz & Bluyssen, 2018), while the field study was divided into qualitative methods (interviews) and quantitative methods (IEQ monitoring, energy readings, checklist). The value of having a mixed-methods approach is that it provides a holistic perspective of the concept of comfort for each of the archetypes. Knowledge is gained not only about what at are "comfortable"' conditions for the participant (environmental monitoring), but also about the extra dimensions of comfort for the archetype, how they are achieved, and which actions or strategies are exercised to achieve them. Ethical approval from the Ethics Committee of the TU Delft was granted to distribute the questionnaire and to perform the field study.

4.2.2 Questionnaire (quantitative data)

Volunteers were drawn from four sources and were invited to take part in the questionnaire. The first and second sources included students from the Delft University of Technology in The Netherlands: 218 master students and 316 bachelor students respectively. The third source was from 1000 employees of the same university, and the fourth from 452 employees of Saint Gobain Recherche in France. The objective was to obtain a sample of a variety of young adulthood and middle adulthood participants that would be representative of diverse home and occupancy types (renters, owners, family homes, student homes, studios). The invitation process started by notifying the potential participant about the purpose of the study one week before they would receive an email with a link to the questionnaire. Participation was voluntary. Participants were given two weeks to fill it out. The first page of the questionnaire introduced the respondent to a consent form detailing time to fill it out (about 30 minutes), closing date, possibility of non-answers, and confidentiality and anonymity measures. Participants from the first and second sources received credit-points when answering the questionnaire. The administration of the questionnaire spanned from October 2016 to October 2017, depending on the source.

The questionnaire was created on the Qualtrics online platform and was developed based on a literature review and already-validated questionnaires that were adapted to the contexts of comfort-making behaviours in the home environment (Ortiz & Bluyssen, 2018). Comfort-making behaviours are described as behavioural expressions that the occupant exercises to achieve a state of physical, physiological, or psychological homeostasis; thus bringing one's current state into a neutral one.

The constructs assessed in the questionnaire were based on and adapted from the Theory of Planned Behaviour (Ajzen, 1991). These were locus of control (beliefs), emotions towards the home, attitudes towards energy, and comfort affordances (needs). Table 4.1 shows the definitions of each of the constructs.

TABLE 4.1 Definitions of behavioural constructs included in the questionnaire

Locus of control	The perceived belief of one's control over results of actions (Lefcourt, 2014).
Emotions towards home environment	Affective reactions to a stimulus that influence one's motivations to behave in specific manners (Ortony et al., 2012)
Comfort affordances	Elements offered by the environment that allow achieving certain goals (McGrenere & Ho, 2000)
Attitudes towards energy	Appraisal of an environmental stimulus that affects thoughts and actions (Perloff, 2010)

A first version of the questionnaire was sent to a panel of reviewers for input on content validity, language use, and layout, and was pilot-tested with twenty individuals (excluded from the final sample) to point out typing or language errors, language clarity, contingency and skipped questions, and time to fill out. The questionnaire was revised accordingly. Simultaneously, Dutch and French translations were made and submitted to reviewers. The final instrument consisted of 65 questions assessing seven categories (demographic and building information, locus of control, emotions towards home environment, comfort affordances, attitudes towards energy, energy-consuming habits, and health and sick building syndrome) [34]. Answers to the questions were presented either dichotomously or on a 5-point Likert scale.

4.2.3 Field Study (mixed data)

The field study involved qualitative and quantitative data collection. Recruitment of participants was done by emailing the questionnaire respondents that showed interest in a follow-up to the questionnaire. Of the 761 questionnaire respondents, 212 gave their address. Invitation emails were sent to participate in the field study and 15 people volunteered.

4.2.3.1 Qualitative field study: Interviews

The qualitative part involved in-depth, semi-structured interviews that were conducted in June and July 2018. Interviews were recorded with a Tascam DR-05 V2 digital audio recorder with the consent of participants. The interviews had three parts: background of the participant, comfort perceptions, and energy consumption habits. Generally, fifteen questions were asked. The main topic was "comfort perceptions"; with a focus on actions performed to achieve comfort or on the building characteristics that allowed achieving comfort. Then those practices were related to the use of energy. During the interview, while a participant explained a practice, the place where the practice is done was shown to visualize their actions and experiences. The interviews of this study are a tool that elicits "technical and process knowledge": explicit knowledge that is readily expressed by participants through what they think and say about a certain topic or from frequently done and repeated patterns of actions and routines (Bogner et al., 2009).

4.2.3.2 Quantitative field study: IEQ monitoring, building features, and energy readings

Measurements were taken of carbon dioxide (CO2), air temperature, and relative humidity (RH). Two types of devices were used: iButton's® and HOBO® MX1102 data loggers. For every interviewee, three iButton's were located in the top three locations that the participant mentioned to spend most time at while being at home. Here referred to as "preferred locations." Measurements were taken for a week and the data acquisition interval was 5 minutes. The HOBO loggers recorded CO2, air temperature, and RH and were placed in the area where the person spent most of their time. HOBOs measured for at least 24 hours.

The actual energy use was determined by reading the gas and electricity meters on the day of the interview and a month later for a second reading. In case night fees were displayed, both readings were recorded. If the person had a smartphone energy-monitoring app, they emailed the data to the researchers. When no energy meter was present due to the social housing company, energy bills were requested. If the person was living in a shared accommodation, estimations were made by dividing the reading by the number of occupants. If the person only had the bills without a breakdown of the consumption, estimations were made based on the gas and electricity fees of their energy supplier.

A checklist was filled out in every home, inventorying building characteristics that play a role in the energy consumption during winter and summer. These were type of home, orientation, construction year, number of rooms, energy label, heating system and terminal units, roof type, general winter temperature, heating season schedules, number of doors to the outside and type of door, percentage of glazing and type, number of windows usually open, solar shading, off-grid power generation, lighting type and appliance usage, and main ventilation strategy.

4.2.4 Data cleaning and analysis

4.2.4.1 Questionnaire: clustering and model validation.

Data from the four questionnaire sources were merged into a master dataset. TwoStep Cluster analysis was performed using SPSS 24.0. Advantages of the method are that data handling is minimal and allows analysing data pertaining to demographics, health, psychographics, and behaviours. The procedure unfolds as follows: first the analysis is run multiple times with different cluster numbers, from 2 to 18; for each run, the ratios of between- and within- cluster variance of the variables are examined: higher ratios imply better cluster separation. A 5-cluster model was chosen for further inspection as it showed the highest ratio. Next, the chosen model was validated. Validation is done to evaluate if the final clusters are influenced by the method, population chosen, and to protect against variables being randomly selected. The validation is a four-step process as proposed by Norusis, and performed as follows: a) ensure that the silhouette measure of cohesion is above 0.0 (in this case 0.2); b) perform Chi2 tests and t-tests to ensure statistical significance of behavioural constructs. This step is done by running the test and removing the behavioural constructs that are not consistent separators; c) remove variables with a prediction score lower than 0.02, and d) halve the sample randomly and apply the final model to each half, ensuring that the results are similar. After the four-step validation was successful, the initial 65 variables of the questionnaire pertaining to behavioural constructs were reduced to 28 variables making up the final model of five distinct occupant clusters.

Further Chi2 analyses were used to test distribution differences between clusters in personal and building variables (gender, age, country, educational level, building type, tenure type, type of cohabitants, number of cohabitants, tenure, time of residence, size in square meters, number of rooms, diseases in the last twelve months, and source of subject). Descriptive statistics of each cluster were

also produced, as frequencies, percentages, maximums and minimums, means and standard deviations, in order to produce a more complete picture of the final archetypes.

4.2.4.2 Interviews: text mining.

Interviews were analysed quantitatively by using a text mining method: sentiment analysis. Preparing the data for text mining required to first transcribe the interviews. Then, a spreadsheet was created with each question per row and the transcription of each respondent per column. The spreadsheets were divided by cluster, to analyse the answers per cluster. Each cluster had an answer spreadsheet that was imported for analysis to SPSS Text Analytics for Surveys 4.

Text mining is an analysis method that extracts meaningful information from large amounts of data from open-ended responses. It does so by identifying themes and analysing words in the texts to find patterns. Text mining analyses the answers by treating subjectivity and sentiment in a quantitative manner. Three outputs result from the analysis. First, the software's linguistic resources extract words and their synonyms that the engine considers important for the analysis; these words are referred to as 'concepts'. Second, during the extraction of concepts, the semantically similar concepts are grouped into 'types'. Third, 'concept patterns' are produced; these are the combination of a single concept with a type. Combining concepts with types is a way to understand the sentiment of the respondents towards a certain topic (CORPORATION, 2012; Siddiqi, 2014).

4.2.4.3 IEQ, building features, and energy readings: statistical analysis.

Questionnaire, IEQ monitoring, and energy data were tested for normality with the Kolmogorov-Smirnov and the Shapiro-Wilk tests. Data from the i-Buttons and the HOBOs were downloaded as excel files and imported to SPSS Statistics. Files from both sources were individually checked to ensure that no extraneous readings had occurred, i.e. direct sunlight on sensors, etc. The checklist data were transferred from the paper forms to SPSS. The results of the checklist presented here only deal with summer-related energy consuming variables. Finally, the results of the field study were studied per cluster, and they were compared and related to the results of the TwoStep analysis.

4.3 Results

4.3.1 General results

Of the 1986 invitations, 969 people responded to the questionnaire, of which 761 completed it, representing a response rate of 48.7% and a completion rate of 78.5%. Table 4.2 shows the distribution of the four sources of respondents.

TABLE 4.2 Distribution of groups of respondents

Source	Survey Invitations n (%)	Survey Respondents n (%)	Field study Invitations* n (%)	Field study Participants n (%)
TU Delft Staff	1000 (50.4)	284 (37.3)	0 (0.0)	0 (0.0)
SGR Staff	452 (22.8)	83 (10.9)	49 (59.0)	0 (0.0)
BSc Students	316 (15.9)	224 (29.4)	72 (32.1)	6 (8.3)
MSc Students	218 (11.0)	170 (22.4)	91 (53.5)	9 (9.8)
Total	**1986 (100)**	**761 (100)**	**212 (27.8)**	**15 (7.1)**

* *Staff members from TU Delft could not provide their e-mail address due to confidentiality reasons.*

The sample was made of 52.6% men and 47.4% women, the most common level of education was a completed master's degree (38.2%) followed by completed primary or secondary school (30.0%). The main building type among the sample was the row house with 29.3%, followed by apartments (24.8%), and semidetached houses (16.6%). 50% of participants reported to live with housemates and 23.4% with family members. 80% were renters, therefore not representing the tenure ratio of the Dutch housing stock which is over 40% (Itard, Meijer, Vrins, & Hoiting, 2008).

28% of respondents provided their email address and were invited to the field study. Of those 212 invitations, fifteen participated in the field study. The recruitment process for the field study required special selection as it was intended to have at least one representative of each cluster in the field study. For the descriptives of the statistics, refer to Appendix D.

4.3.2 Cluster results

The questionnaire data was tested for normality with the Kolmogorov-Smirnov and the Shapiro-Wilk tests, and no violations were found. Table 4.3 shows the five clusters identified by the TwoStep analysis and the 28 behaviour-related variables composing the model.

The final model comprised variables from three constructs: emotions towards home (negative and positive), comfort affordances, and locus of control (internal and external).

Of the variables pertaining to personal and building characteristics, rather than psycho-behavioural (Table 4.4), statistically significant differences were found for age ($p=0.001$), tenure type ($p=0.004$), number of rooms ($p<0.001$), time residing in home ($p=0.001$), cohabitant type ($p<0.001$), educational level ($p=0.02$), and psychiatric problems ($p=0.001$).

TABLE 4.3 Variables composing the final model (Mean (SD)).

Archetype	Archetype 1	Archetype 2	Archetype 3	Archetype 4	Archetype 5
	Restrained conventionals	Incautious realists	Positive savers	Sensitive wasters	Vulnerable pessimists
Positive emotions towards home					
1: I don't feel this at all – 5: I feel this strongly					
Pride	3.3 (0.9)	3.1 (0.9)	3.8 (1.0)	3.8 (1.2)	2.3 (1.2)
Admiration	2.5 (1.0)	2.6 (1.0)	2.8 (1.4)	3.1 (1.3)	1.9 (1.1)
Satisfaction	3.8 (0.6)	3.4 (0.8)	4.4 (0.6)	4.3 (0.7)	2.9 (1.1)
Joy	3.7 (0.7)	3.4 (0.7)	4.2 (0.7)	4.1 (0.9)	3.0 (1.1)
Fascination	2.6 (1.1)	3.0 (1.0)	3.4 (1.3)	3.7 (1.3)	2.3 (1.3)
Negative emotions towards home					
1: I don't feel this at all – 5: I feel this strongly					
Shame	1.4 (0.7)	2.1 (1.0)	1.2 (0.4)	1.3 (0.7)	1.9 (1.1)
Dissatisfaction	1.8 (0.8)	2.5 (1.0)	1.3 (0.6)	1.5 (0.9)	2.8 (1.3)
Disgust	1.4 (0.7)	2.1 (1.0)	1.1 (0.5)	1.1 (0.4)	2.0 (1.1)
Boredom	1.8 (0.8)	2.5 (1.1)	1.4 (0.7)	1.6 (0.9)	2.3 (1.3)
Comfort affordances					
1: I don't need it to feel comfortable – 5: very important for my comfort					
Lighting quality	3.8 (0.8)	3.3 (0.9)	3.7 (0.9)	4.2 (0.9)	3.8 (1.1)
Freedom of action	4.0 (0.8)	3.6 (0.8)	3.7 (0.9)	4.7 (0.6)	4.0 (1.1)
Control of systems	3.4 (0.9)	3.2 (0.8)	3.3 (1.2)	4.5 (0.8)	3.3 (1.4)
Freedom of being	3.9 (0.9)	3.7 (0.9)	3.6 (1.2)	4.6 (0.8)	3.5 (1.3)
Privacy	4.2 (0.7)	3.8 (0.9)	3.9 (1.0)	4.7 (0.7)	3.6 (1.3)
Spatial quality (layout and size)	3.9 (0.8)	3.3 (0.9)	3.4 (1.0)	4.6 (0.8)	3.7 (1.3)
Internal Control (Read carefully each of the following statements and select a number from 1 to 5, according to how you feel about them.)					
1: strongly disagree – 5: strongly agree					
Freedom of action	3.7 (0.9)	3.1 (1.0)	4.1 (1.1)	4.5 (0.9)	3.2 (1.3)
Privacy	3.0 (0.9)	2.7 (1.1)	3.1 (1.3)	3.8 (1.4)	2.8 (1.3)
Order and cleanliness	4.1 (0.8)	3.7 (1.0)	4.2 (0.9)	4.8 (0.5)	4.1 (1.2)
Climate	2.9 (1.0)	2.6 (1.2)	3.0 (1.3)	3.7 (1.5)	2.6 (1.5)
Relaxation	3.6 (0.8)	2.8 (1.0)	3.5 (1.3)	4.3 (1.1)	3.5 (1.4)
Atmosphere	3.5 (0.8)	3.0 (1.0)	3.6 (1.0)	4.4 (1.0)	3.5 (1.3)
Personalization	3.6 (0.7)	3.1 (1.0)	3.8 (0.8)	4.6 (0.9)	3.4 (1.3)
External Control (Read carefully each of the following statements and select a number from 1 to 5, according to how you feel about them.)					
1: strongly disagree – 5: strongly agree					
Privacy	2.6 (0.9)	2.4 (1.0)	1.6 (1.0)	1.8 (1.2)	2.4 (1.3)
Climate	3.2 (0.9)	2.8 (1.1))	2.2 (1.2)	2.4 (1.5)	3.5 (1.4)
Relaxation	2.4 (0.9)	2.4 (1.1)	1.6 (1.2)	2.2 (1.4)	2.4 (1.3)
Atmosphere	2.6 (0.8)	2.7 (1.1)	1.9 (1.1)	2.0 (1.3)	2.7 (1.3)
Personalization	2.6 (0.9)	3.1 (1.0)	1.9 (1.3)	2.1 (1.5)	2.5 (1.4)
Mood	2.8 (0.9)	2.7 (1.2)	2.4 (1.3)	2.6 (1.5)	2.7 (1.4)

TABLE 4.4 Personal and building characteristics with statistically significant differences between clusters and their p-value per archetype

Variable	Total	Archetype 1	Archetype 2	Archetype 3	Archetype 4	Archetype 5	p-value
		Restrained conventionals	Incautious realists	Positive savers	Sensitive wasters	Vulnerable pessimists	
Age – Mean (SD)							**0.001**
	28.5 (10.9)	25.4 (9.0)	27.3 (9.3)	33.9 (12.8)	32.8 (12.5)	26.1 (8.5)	
Tenure							**0.004**
Owner	**99 (21.0)**	48 (24.5)	13 (15.3)	15 (36.6)	13 (22.8)	10 (10.8)	
Renter	**373 (79.9)**	148(75.5)	72 (84.7)	26 (63.4	44 (77.2)	83 (89.2)	
Number of rooms (SD)							**0.001**
	3.9 (1.4)	3.9 (1.4)	4.3 (1.2)	4.1 (1.3)	3.4 (1.5)	3.7 (1.5)	
Time residing in the house							**0.001**
Less than 6 months	**147 (30.9)**	42 (21.3)	19 (22.4)	15 (35.7)	33 (57.9)	38 (40.4	
6 to 12 months	**74 (15.6)**	31 (15.7)	17 (20.0)	6 (14.3)	8 (14.0)	12 (12.8	
1 - 5 years	**165 (34.7)**	77 (39.1)	34 (40.0)	10 (23.8)	10 (17.5)	34 (36.2	
More than 5 years	**83 (17.5)**	44 (22.3)	14 (16.5)	11 (26.2)	5 (8.8)	9 (9.6)	
Cohabitant type							**0.001**
Family members	**111 (23.4)**	55 (27.9)	16 (18.8)	16 (38.1)	9 (15.8)	15 (16.0)	
Housemates	**238 (50.1)**	93 (47.2)	56 (65.9)	14 (33.3)	21 (36.8)	54 (57.4)	
(Un)married couple	**52 (10.9)**	24 (12.2)	4 (4.7)	4 (9.5)	9 (15.8)	11 (11.7)	
Alone	**74 (15.6)**	25 (12.7)	9 (10.6)	8 (19.0)	18 (31.6)	14 (14.9)	
Educational level							**0.02**
Primary or Secondary school	**227 (30.0)**	94 (42.2)	61(35.9)	20 (14.6)	15 (13.3)	37 (31.6)	
Some college	**7 (0.9)**	2 (0.9)	2 (1.2)	0 (0.0)	3 (2.7)	0 (0.0)	
Completed Bachelors	**116 (15.3)**	26 (11.7)	13 (7.6)	13 (9.5)	28 (24.8)	36 (30.8)	
Completed Masters	**289 (38.2)**	66 (29.6)	73 (42.9)	75 (54.7)	48 (42.5)	27 (23.1)	
Doctorate	**49 (6.5)**	27 (12.1)	2 (1.2)	6 (4.4)	4 (3.5)	10 (8.5)	
Professional	**69 (9.1)**	8 (3.6)	19 (11.2)	21 (15.3)	14 (12.4)	7 (6.0)	
Psychiatric problems							**0.01**
	31 (4.2)	7 (3.3)	14 (8.2)	3 (2.2)	0 (0.0)	7 (6.0)	

P-values in bold refer to significant relationships at 5% level.

4.3.3 Interview text mining

The text mining analysis was performed per cluster and per question; however, as some of the questions belonged to the same sub-themes; their results were merged into categories. The categories are “energy awareness and motivations of usage”; “general comfort and perfect home”; “sense of control”; and “affordances”. Affordances are individually presented as freedom, temperature, smells, lights, acoustics, privacy, cleanliness, and security.

TABLE 4.5 Percentage of positive sentiments per topic discussed and means per category per archetype

Topic (question)	Archetype 1	Archetype 2	Archetype 3	Archetype 4	Archetype 5
	Restrained conventionals	Incautious realists	Positive savers	Sensitive wasters	Vulnerable pessimists
Psychobehavioral					
Energy awareness and use	60.0	100.0	25.0	33.3	50.0
General comfort and future home	100.0	66.7	75.0	100.0	100.0
Sense of control	75.0	66.7	0.0	100.0	75.0
Mean psychobehavioral	**78.3**	**77.8**	**33.3**	**77.8**	**75.0**
Affordances					
Freedom	0.0	100.0	100.0	0.0	100.0
Temperature	100.0	100.0	100.0	33.3	0.0
Smells	0.0	100.0	100.0	50.0	100.0
Lights	60.0	0.0	50.0	66.7	42.9
Acoustics	20.0	100.0	100.0	40.0	0.0
Privacy	66.7	100.0	100.0	50.0	100.0
Cleanliness	100.0	50.0	0.0	100.0	50.0
Security	66.7	50.0	100.0	50.0	25.0
Mean affordances	**51.7**	**85.7**	**92.9**	**48.8**	**52.2**
Full interview	**65.0**	**81.7**	**63.1**	**63.3**	**63.6**

The results of the table show the positive percentages of a linear scale. Therefore, the percentage of “negative sentiments” is the inverse of the results of the table

Table 4.5 shows the percentage of positive sentiments per archetype and per question and the means for each category. Positive ‘types’ produced by the text mining are grouped together. From the table it can be seen that the Incautious Realists (Archetype 2) have the most positive opinions about energy awareness and usage, while the Positive savers (Archetype 3) have the most negative ones. The Vulnerable Pessimists (Archetype 5) has equally positive and negative opinions about energy awareness and usage. For “general comfort and future

TOC

home", Restrained Conventionals, Sensitive wasters, Vulnerable pessimists (Archetypes 1; 4; 5) did not express negative opinions; while Archetypes 2 and 3 only expressed 33% and 25% negative opinions, specifically in terms of "air"; "ceiling lamps"; and "freedom".

Looking at the means, the results imply that the Positive Savers (Archetype 3) expressed the most positive opinions for affordances, with 93 %. The most negative opinions expressed for this topic came from the Sensitive Wasters (Archetype 4), with 49 %. For "Psycho-behavioural", Positive savers (Archetype 3) expressed most negative opinions with 67%, and 78% of opinions about "Psycho-behavioural" expressed by Restrained Conventionals (Archetype 1) were positive. For the full interview all Archetypes expressed between 63% and 65% of positive opinions, except for Incautious Realists (Archetype 2) for which almost 82% of opinions expressed in the entire interview were positive.

The detailed results of the text mining analysis are presented in Appendix D and are presented according to the output of the SPSS Text Analytics.

4.3.4 IEQ and energy readings

The field study data was also tested for normality with the Kolmogorov-Smirnov and the Shapiro-Wilk tests, and due the sample size, it was not normally distributed. Descriptive statistics were produced for the energy readings and IEQ monitoring data per archetype. Table 4.6 presents the electricity and gas readings during a month in the summer of 2018. Results propose that there is a large variation in gas and electricity. Due to the low number of participants (fifteen), it was deemed insufficient to perform a statistical comparison of means. It is worth mentioning that in the Netherlands, the average gas and electricity consumption per person per month is 54 m3 and 150 kWh respectively (Milieucentraal, 2019). By treating the archetypes as case studies, from least wasting to most wasting, the archetypes can be ranked as 3; 1; 5; 2; and 4.

TABLE 4.6 Energy consumption readings per archetype (m³ for gas and kWh for electricity in 1-month period)

Archetype			Median (min;max)
Archetype 1	Restrained conventionals	Gas	98 (59; 501)
		Electricity	297 (97; 774)
Archetype 2	Incautious realists	Gas	419 (64; 774)
		Electricity	394 (170; 617)
Archetype 3	Positive savers	Gas	9 (0; 17)
		Electricity	81 (66; 96)
Archetype 4	Sensitive wasters	Gas	624 (272; 774)
		Electricity	617 (421; 895)
Archetype 5	Vulnerable pessimists	Gas	165 (47; 774)
		Electricity	300 (80; 617)

Mann-Whitney and Kruskal-Wallis tests were performed to check whether statistical significance exists between measured temperatures and profile. However, as aforementioned, due to the small number of participants, such analysis is inconclusive. Nevertheless, based on the means presented in Table 4.7, it can be suggested that Restrained Conventionals (Archetype 1) have lower temperatures, while the Incautious realists (Archetype 2) have the highest temperatures.

Table 4.8 shows the results of the HOBOs as medians and quartiles of CO2 and RH taken during 24 hours in the location where the participant spends most of their time. Statistical analyses were deemed unnecessary due to the small sample. However, it can be seen that the Positive Savers (Archetype 3) present the lowest concentrations of CO2 (447 ppm) while the Vulnerable Pessimists (Archetype 5) have the highest ones (746 ppm). Concerning RH, the Incautious realists (Archetype 2) have the lowest measurements (53%) while the highest ones belong to the Restrained Conventionals (Archetype 1) with 59%. All CO2 and RH results are within the regular levels.

TABLE 4.7 Temperature of "preferred" locations with iButton's per Archetype and Participant and outdoor temperature in degrees Celsius (1-week period)

Interviewee (Archetype*)	Indoor Location 1	Indoor Location 2	Indoor Location 3	Average outdoor daily temperature	Average outdoor minimum	Average outdoor maximum	Dates
Interviewee 1 (1)	21.5	22.5	21.8	17.4 (1.6)	12.9 (1.6)	22.5 (3.7)	6.6.18 - 13.6.18
Interviewee 2 (1)	23.0	22.5	22.3	16.4 (1.5)	13.1 (1.4)	20.0 (3.4)	15.6.18 - 22.6.18
Interviewee 3 (1)	23.3	21.7	23.8	15.5 (1.4)	10.0 (1.4)	20.2 (2.7)	20.6.18 - 27.6.18
Interviewee 4 (1)	22.1	22.1	22.3	16.5 (1.3)	10.1 (1.2)	21.7 (2.6)	22.6.18 - 29.6.18
Archetype 1 Median (P25; P75)	**22.5 (21.8; 23.5)**	**22.1 (21.5; 23.9)**	**22.5 (21.9; 23.5)**	**16.5**	**11.5**	**21.1**	
Interviewee 5 (2)	24.0	25.0	Na	17.0 (1.1)	13.1 (1.3)	21.3 (2.4)	8.6.18 - 15.6.18
Interviewee 6 (2)	28.6	27.8	28.2	20.1 (1.2)	13.2 (1.1)	26.4 (2.1)	28.6.18 - 5.7.18
Archetype 2 Median (P25; P75)	**26.8 (24.0; 28.6)**	**26.0 (25.0; 27.9)**	**28.3 (27.5; 28.0)**	**18.6**	**13.2**	**23.8**	
Interviewee 7 (3)	23.5	21.5	21.9	17.2 (1.5)	13.2 (1.3)	21.8 (2.5)	7.6.18 - 14.6.18
Interviewee 8 (3)	23.5	23.6	23.3	17.0 (2.2)	13.9 (2.7)	20.7 (2.9)	13.6.18 - 20.6.18
Archetype 3 Median (P25; P75)	**23.5 (23.0; 24.1)**	**23.4 (21.5; 23.6)**	**22.7 (21.8; 23.5)**	**17.1**	**13.5**	**21.2**	
Interviewee 9 (4)	21.8	21.7	22.1	17.5 (2.1)	13.0 (3.5)	22.6 (2.6)	5.6.18 - 12.6.18
Interviewee 10 (4)	26.3	26.7	26.6	16.6 (2.1)	13.6 (3.3)	19.7 (2.6)	12.6.18 - 19.6.18
Interviewee 11 (4)	23.6	23.6	24.6	19.9 (2.1)	13.2 (3.1)	26.2 (2.7)	29.6.18 - 6.7.18
Archetype 4 Median (P25; P75)	**23.9 (22.3; 25.8)**	**24.0 (22.3; 26.3)**	**24.7 (23.5; 26.1)**	**18.0**	**13.2**	**22.8**	
Interviewee 12 (5)	23.0	22.0	22.0	16.5 (2.7)	13.2 (2.3)	19.9 (3.8)	11.6.18 - 18.6.18
Interviewee 13 (5)	26.2	26.2	22.1	17.5 (2.8)	13.0 (2.6)	22.6 (3.8)	5.6.18 - 12.6.18
Interviewee 14 (5)	23.1	23.1	23.1	15.9 (2.7)	12.3 (2.5)	19.5 (3.8)	16.6.18 - 23.6.18
Interviewee 15 (5)	25.1	25.6	25.1	15.6 (2.7)	10.5 (2.5)	19.9 (3.6)	19.6.18 - 26.6.18
Archetype 5 Median (P25; P75)	**24.6 (22.9; 25.4)**	**24.0 (22.4; 25.6)**	**23.0 (22.0; 24.9)**	**16.4**	**12.2**	**20.5**	

* *Archetype 1: Restrained conventionals; Archetype 2: Incautious realists; Archetype 3: Positive savers; Archetype 4: Sensitive wasters; Archetype 5: Vulnerable pessimists*

TABLE 4.8 Carbon dioxide and relative humidity per Archetype and Participant (24-hour period)

Interviewee (Archetype*)	CO_2 (ppm)	RH (%)
	Median	Median
Interviewee 1 (1)	533	64.1
Interviewee 2 (1)	399	53.9
Interviewee 3 (1)	503	64.3
Interviewee 4 (1)	439	56.4
Archetype 1 Median (P25; P75)	**431 (399; 512)**	**56.4 (53.3; 59.2)**
Interviewee 5 (2)	635	59.4
Interviewee 6 (2)	475	47.7
Archetype 2 Median (P25; P75)	**537 (463; 671)**	**58.0 (50.3; 59.9)**
Interviewee 7 (3)	501	60.6
Interviewee 8 (3)	417	45.9
Archetype 3 Median (P25; P75)	**446 (381; 512)**	**57.9 (46.2; 61.0)**
Interviewee 9 (4)	892	64.1
Interviewee 10 (4)	545	46.3
Interviewee 11 (4)	466	41.3
Archetype 4 Median (P25; P75)	**508 (441; 658)**	**47.9 (39.4; 56.6)**
Interviewee 12 (5)	437	50.5
Interviewee 13 (5)	351	57.9
Interviewee 14 (5)	556	58.5
Interviewee 15 (5)	1181	64.7
Archetype 5 Median (P25; P75)	**519 (394; 1036)**	**58.0 (55.3; 62.4)**

* *Archetype 1: Restrained conventionals; Archetype 2: Incautious realists; Archetype 3: Positive savers; Archetype 4: Sensitive wasters; Archetype 5: Vulnerable pessimists*

Table 4.9 shows the descriptive statistics of the building checklist. The groups seem to differ considerably in certain aspects: i.e. the number of showers taken per week and their duration ranging from 5.5 to 9.3 showers a week and between 9.3 to 22.5 minutes per shower. More differences exist for behavioural aspects, such as the amount of time windows are open during the summer. None of the participants had air conditioning in their homes.

TABLE 4.9 Summer-related energy variables from building checklist per archetype*.

Archetype	Archetype 1	Archetype 2	Archetype 3	Archetype 4	Archetype 5
	Restrained conventionals	Incautious realists	Positive savers	Sensitive wasters	Vulnerable pessimists
Number of windows open in summer / mean (SD)					
	3.0 (2.3)	1.0 (0.0)	1.5 (0.5)	0.7 (0.4)	1.0 (0.0)
When are windows open					
All day	25	0	0	33	25
All day and all night	75	50	0	0	50
All Morning	0	50	50	0	0
Afternoon	0	0	0	0	25
All night	0	0	50	33	0
Never	0	0	0	33	0
Ventilation grilles					
Ventilation grilles present	50	50	50	67	0
Opening of grills frequency					
Never	50	100	0	33	100
Sometimes	0	0	100	0	0
Often	25	0	0	0	0
Always	25	0	0	67	0
Percentage of laundry in drier					
I have no drier	50	50	50	33	50
10	25	0	0	0	0
50	25	0	0	0	25
75	0	0	50	33	25
100	0	50	0	33	0
Fridge type					
With freezer	100	50	50	67	50
No freezer	0	50	50	67	50
Freezer only	0	0	0	0	25
Oven and stove type					
Electric both	50	100	0	33	100
Gas both	0	0	50	0	0
Gas stove and electric oven	50	0	50	0	0
Gas stove. no oven	0	0	0	33	0
Electric stove. no oven	0	0	0	33	0
General ventilation strategy					
Natural	25	0	50	33	25
Natural assisted (exhaust)	75	100	50	67	75

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TABLE 4.9 Summer-related energy variables from building checklist per archetype*.

Archetype	Archetype 1	Archetype 2	Archetype 3	Archetype 4	Archetype 5
	Restrained conventionals	Incautious realists	Positive savers	Sensitive wasters	Vulnerable pessimists
Exhaust system location					
Toilet	25	0	0	50	33
Kitchen	25	0	50	50	0
Kitchen and toilet	50	0	0	0	0
Other (permanent)	0	100	0	0	67
Weekly number of showers and duration / Mean (SD)					
Per week	8.3 (3.9)	6.5 (0.5)	5.5 (0.5)	9.3 (3.3)	7.0 (0.0)
Duration minutes	15 (7.0)	22.5 (2.5)	10.0 (4.0)	15.0 (0.0)	9.3 (1.3)

* *The total of the percentages may not be 100% since in some cases one participant may have chosen more than one answer.*

4.3.5 Final Archetype descriptions

Based on the questionnaire results, the variables comprising the model, the text mining outcomes, and the energy readings, the following archetypes are presented and labelled as follows: Restrained Conventionals, Incautious Realists, Positive Savers, Sensitive Wasters, and Vulnerable Pessimists.

Figure 4.2 shows the differences in relative values of each archetype. The names of the archetypes are based on their most extreme features shown by the descriptives from the variables of the questionnaire and the energy readings. The labelling was done as follows: if an archetype has the highest or lowest score for a certain variable, the variable attribute is used to label them. If two archetypes have the same variable as their highest one, the archetype that had the highest score is labelled with the variable attribute, and the second highest variable is used for the other archetype. The labels of the figure are based on the energy readings, interview variables, and statistical model variables. Namely, emotions (positive and negative), control (internal and external based on locus of control), and affordance sensitivity are variables from the statistical model. Energy use and awareness, general comfort, control of environment, and affordance opinions, are based on the results of positive and negative sentiments of opinions of the interview questions. Finally, actual energy reflects the energy readings from the field study. In some cases, for example 'affordance opinions' all the questions related to different affordances (light, temperature, privacy, cleanliness, etc.) were combined into a single label.

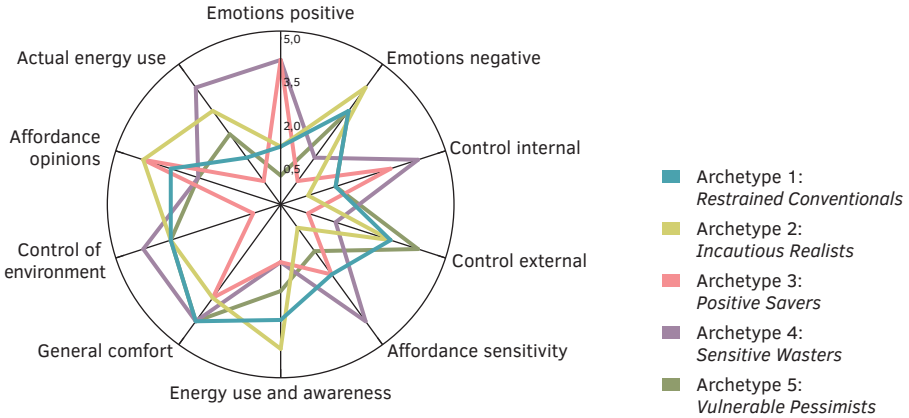


FIG. 4.2 Visual comparison of relative values of different variables per archetype.

Restrained Conventionals (Archetype 1)

The Restrained Conventionals (RCs) is the largest archetype, representing 29.4% of the sample and is the youngest group (mean age: 25.4 years). RCs reported to generally have higher-than-average negative emotions, and low positive emotions, while having high external and low internal control. In interviews, RCs expressed positive opinions for energy motivations, comfort, and sense of control, but a general ambivalence of opinions about affordances. They are the second lowest energy consumer, as 50% of them mentioned to use the drier for 10 to 50% of laundry, and the other half does not own one. They reported the second smallest weekly number of showers (8.3), but they spend the second longest time showering (15 minutes). They had the third highest concentrations of CO2, yet 100% claimed to open the windows "all day and all night" during the summer. It is worth mentioning that Interviewee 2 from this archetype did not occupy the house while the CO2 measurements were taken.

Incautious realists (Archetype 2)

The Incautious Realists are the second largest cluster (22.3%) and have a mean age of 27.3 years (SD: 9.3). 66% of IRs live with housemates and only 10% live alone. This is the second largest renter group (85% renters). IRs have the highest rating of negative emotions, while having low positive emotions. They score lowest in internal locus of control, and higher-than-average external control. They expressed relative

positive opinions about their general affordance and psycho-behavioural topics. They are the second largest waster, according to the energy readings, correlating with the longest showers (22.5 minutes). Yet they take the second smallest weekly amount of showers (6.5). 50% dry their laundry in the drier and 50% do not have one. They have the lowest concentrations of CO2, which relates to all of them having a permanent exhaust.

Positive savers (Archetype 3)

The Positive Savers (PSs) are the third largest cluster (18.0%) and the oldest (33.9 years). 38.1% live with family members, and is the second largest (19.0%) with people living alone. PSs show the second highest ratings in positive emotions, and lowest for negative emotions. They have the lowest scores in external control, and second highest scores in internal control. PSs expressed very highly positive opinions about affordances and slightly negative ones about comfort and energy. According to energy readings, they are the biggest savers, supported by the fact that 50% of them do not own a drier and that rest uses it for 75% of their laundry. They report the smallest weekly number of showers (5.5) and the second shortest showers (10.0 minutes). The have the lowest CO2 concentrations, yet this is not reflected on the reported window opening behaviours or exhaust features. Interviewee 8, who spent the day and night away during the CO2 recordings, also influences this.

Sensitive wasters (Archetype 4)

The Sensitive Wasters (SWs) is the smallest group (14.8%) and has the second oldest mean age of 32.8 (SD: 12.5). 32% of SWs live alone -the highest of all groups- while being the third largest home-owning cluster (22.8%). They scored the highest in positive emotions, and the second lowest in negative emotions. They have the highest internal control scores and second lowest external control. SWs expressed positive opinions about comfort and control of the environment topics but negative ones about energy awareness, while half of their opinions about affordances were positive. They are the highest consumers, reflected on the fact that some of them have more than one fridge, and 66.7% claim to dry 75%-100% of their laundry in the drier. CO2 registered the second highest concentrations, correlating with the report that 33.3% never open the windows during the summertime; however 66.7% claim to have ventilation grilles constantly open.

Vulnerable pessimists (Archetype 5)

The Vulnerable Pessimists (VPs) are the second youngest group (26.1 SD: 8.5). They represent the second largest group living with housemates (57.4%) and largest renters (89.2%). They score lowest in positive emotions and second highest in negative emotions, while having the highest external control scores, and second lowest in internal control. They expressed ambivalence on energy awareness, control of environment, and affordances, but positive sentiments with general comfort. They are the third largest waster according to energy readings, and 50% dry 50%–75% of their laundry in the dryer. CO2 recorded the highest concentrations, which relates to their report of never opening grilles. However, 50% do open one window all day and all night in the summer, nevertheless, 66.7% have a permanent extractor.

4.4 Discussion

In this study using qualitative and quantitative techniques, five occupant archetypes were produced based on the answers of 761 participants and 15 interviewees. The basis of these archetypes were the responses to the specialized questionnaire related to behavioural constructs, namely emotions, control, and needs; with which statistical clusters were produced by using the strongest separating variables. In a previous study involving the same questionnaire but only 193 respondents, the TwoStep cluster analysis produced six clusters. The model of that study was different since it had one more cluster, but also because the segmentation variables included attitudinal variables. In this study, attitude variables were not strong separators to make up the model. An argument for the fact that attitudinal variables were not consistent separators could be that the questions were not correctly formulated, even though they were adapted from an already validated instrument. Another argument could be the fact that the questionnaire did not discern between cognitive and affective attitudes (conscious vs unconscious), and hence dissonance of answers could have created weak separators Compared with the current model, in general, the last three archetypes remained the same, while Archetype 1 merged with 3. However, the previous model, having only 193 respondents, was not as reliable as the one of the present study due to its low number of respondents being less appropriate for the clustering technique.

The goal of archetypal data is to allow customizing technologies that will improve health and comfort of each archetype, while reducing energy consumption. The archetypes are described below by emphasizing their differences between energy use and energy attitudes, and their stress-related factors (emotions and control). Understanding the archetypes from these lenses can give insights into what sort of interventions or lines-of-action could be implemented in their homes to help reduce their energy and increase comfort. The Incautious Realists exemplifies a group that should be treated with higher priority. This is because it is the second largest group, and they report the lowest internal control, higher rates of negative emotions, higher wasting patterns, neglectfulness of comfort affordances, and highest frequency of health issues. It concords with the results of studies that propose interactions between locus of control, stress levels, and levels of illness: specifically with the links found between stress and the prevalence of cardiovascular disease, allergies, or healing time (Byrnes et al., 1998; Costanzo et al., 2004; Kiecolt-Glaser et al., 2002; Marsland, Walsh, Lockwood, & John-Henderson, 2017; Roddenberry & Renk, 2010; Wirtz & von Känel, 2017). In addition this group shows what it is known as attitude-behaviour gap, as they express positive awareness about energy, yet they are relatively high wasters (Claudy, Peterson, & O'Driscoll, 2013). At the other end of the spectrum, the Sensitive Wasters represent the second healthiest group, with highest internal control and positive emotions scores, however, their non-conserving actions are well aligned with their negative views towards energy, which is coupled with their need for comfort and affordances. This high consumption and need for comfort is reflected in studies showing that northern European societies are comfort-oriented energy cultures: they tend to choose to live a comfortable life regardless of the energy needed (Aune et al., 2011). The Positive Savers have a conservative consumption accompanied by seemingly non-green awareness; literature suggests that such incongruence tends to be the result of financial consciousness rather than energy conservation (Kollmuss & Agyeman, 2002; Mills & Schleich, 2012). Restrained Conventionals possess 'green' beliefs which are in line with their low-wasting energy readings; this attitude-behaviour congruency has been proposed to be characteristic of single-occupant homes (Clevenger, Haymaker, & Jalili, 2013; Cui, Goodhew, Fewkes, & Chilton, 2011) however, this is not reflected in this archetype as only 13% live alone. They present high negative emotions and low internal control, which may be an indicator of higher stress levels (Abraham, Conner, Jones, & O'Connor, 2016). Finally the Vulnerable Pessimists are similar to the previous archetype in that they also show an alignment between their energy awareness and their energy consumption, and they present risk factors for high stress and hence for poor health and general wellbeing.

Such differences among archetypes show to a degree how each archetype requires different lines-of-action to achieve comfort, health, and energy expenditure reduction. An example is to develop solutions that support the high external control (belief that the person cannot change the environment) for example with automation, while offering an

indoor environment that will at all times ensure comfort and health. Another example could be offering solutions that support the high control of the environment while taking into account the high sensitivity to affordances. This could be an interface offering controlling different aspects of the environment, while also showing how the changes influence comfort. For the archetypes in which there seems to have higher energy consumption than what their green beliefs postulate, interfaces showing costs and use could be useful. These interventions should operate in such a way that the behaviours specific to the archetypes do not bypass the energy efficiency of the technologies. Such concepts need further research with mixed methods studies and co-creation techniques.

Producing occupant archetypes based on behavioural constructs with mixed-methods is valuable as it enables to better understand the occupant dimension of energy use. Although the archetypes presented in this study are not yet complete, they can shed light onto the occupant mental models, especially in terms of their comfort behaviours.

In the interviews, technical and process knowledge data was collected. This is knowledge that is verbally transmitted and is easily retrieved because it is explicit. Different techniques exist to analyse qualitative interview data, mainly qualitative techniques (i.e. content analysis, coding, and recursive analysis). In this study, a type of text mining was used: sentiment analysis. Two reasons exist for using it: it introduces objectivity to the outcome as it is a quantitative technique and sentiment analysis is used to find emotions expressed by participants (an objective of this study). Due to the sample, the quantitative data of the field study (IEQ monitoring and energy readings) cannot be generalized as part of the archetypes, and should rather be observed as case studies. The small sample of the field study can be valuable, as personal data is rarely utilized in the energy research field. Still, the current sample is not representative of the home occupants of the Netherlands, as a large part of it comprises university students, and Dutch and French employees. This therefore, needs to be considered as an influencing factor of the archetypes, since such a population may introduce bias to the outcomes.

The survey involved only self-reported data, while the interviews yielded technical and process knowledge data, which can also be biased. As shown in the description of the archetypes, the self-reported data from the survey and the process knowledge data from the interviews may appear incongruent or dissonant. This is to be expected as in the interviews, participants reflect on how and why they execute the comfort-actions; and while the possibility exists that what they say may be dissimilar to what they actually do, their verbalizations are valuable to understand their 'process knowledge'. Nevertheless, gathering and combining qualitative and quantitative data is not only to validate each other, but also to reduce potential bias.

Some observations of the human-building interactions are noteworthy. For the air temperature monitoring, no large variations were seen for the top three preferred locations, meaning that the preference for a location is likely unrelated to temperature and related to other spatial attributes; thus temperature and behaviours are unrelated. As far as the building checklist is concerned, it is interesting to note that archetypes tend to live in buildings that present dissimilar characteristics, meaning that the archetypes may not relate to the buildings' features; in other words, it seems that the environment does not shape the archetype. Energy consumption varied greatly across and within archetypes. Such discrepancies cannot be generalized and based on the current collected information it is not possible to say if they are the consequences of behavioural patterns or of the building characteristics. The sample was too small and the period of sampling was too short, thus, further research is necessary for the energy use part of this study.

4.5 Conclusion

This study contributes to better understand the motivations behind comfort behaviours of occupiers in their residences and to see possible energy consumption discrepancies among occupiers with different behavioural patterns. It suggests that combining home occupants from different sources, and analysing their answers to a questionnaire, can be clustered into five distinct groups based on their psychological and behavioural models, related to locus of control, emotions towards their own home environment, and the importance they give to comfort affordances. The findings show that each of the archetypes has distinct valence of opinions when asked about topics regarding energy use, energy awareness, general comfort, and an array of affordances, albeit, what they express verbally is not always congruent to the general results of their self-reported answers. Although IEQ and energy readings were also taken, the sample proved too small to set statistical relationships. Finally, a mixed methods approach seems to be promising to better understand the individual needs of groups of people, and to achieve more energy savings and better comfort levels, as the method allows to have detailed and complete archetypes. Practical uses of the archetypes are that they can be used for improved and more accurate simulation and building prediction models. Additionally, archetypes can be used as part of the design process to develop potential tailor-made lines of action for each archetype: their particular characteristics need to be translated into design parameters, such as interfaces that can give the right feedback to the specific

archetype. Architects, constructors, or housing associations can also use models pairing archetypes to specific building features that support the archetypes mental models, to optimize energy consumption and comfort.

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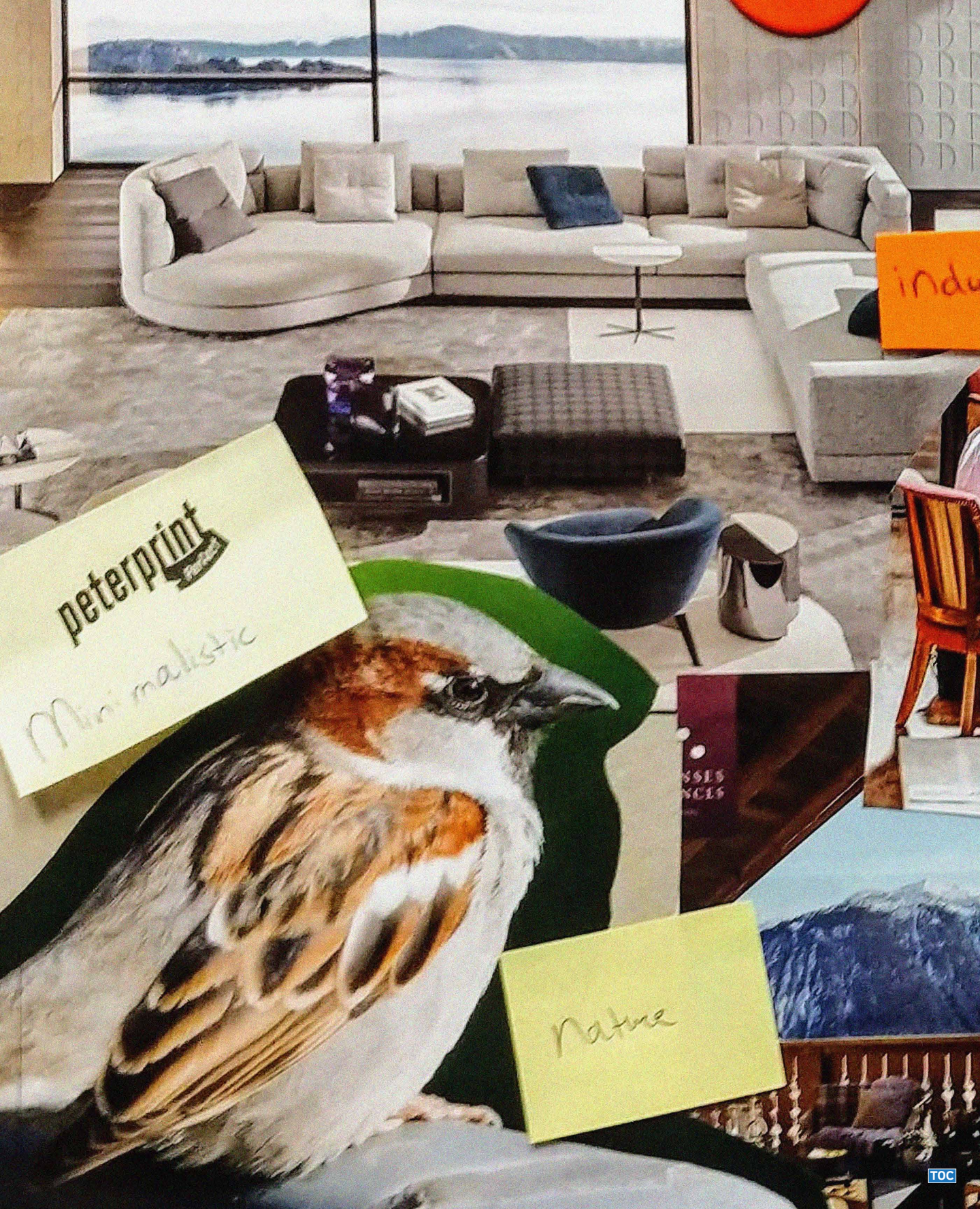
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Minimalistic
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PART 4

Development of the final Archetypes



TOC



TOC

5 Using focus groups data to finalize the Archetypes

Substantiation of Home Occupant Archetypes with the Use of Generative Techniques: Analysis and Results of Focus Groups.

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Substantiation of Home Occupant Archetypes with the Use of Generative Techniques: Analysis and Results of Focus Groups.

ABSTRACT A previous study clustered home occupants into archetypes with a questionnaire. This study uses qualitative methods to strengthen those previously-found archetypes with data pertaining to the participants' home experiences.

Focus groups were carried out where generative activities were conducted involving the generation of collages. The first activity dealt with the expression of 'meaning of energy use at home' and the second one with the 'ideal home experience'. Analyses were done with content and thematic analysis. Codes were drawn from the data and were assimilated through an affinity diagram.

The diagram produced two categories: building themes and human themes, along with five sub-categories (home, financial, energy, psychological, and behavioural aspects). The outcome shows that each archetype expresses needs and meanings of an ideal home experience and energy use differently from each other.

The results provide evidence that generative techniques can be used in energy research. In this case, to validate and substantiate the quantitative archetypes previously produced with a questionnaire. Interpretive knowledge in energy research allows for a better understanding of occupants' differing behavioural patterns in regards to energy use and comfort. It allows customizing interventions to the archetypes' specific needs to decrease energy consumption while maintaining comfort.

KEYWORDS energy use, home, profiles, archetypes, generative techniques

5.1 Introduction

To reduce energy consumption, it is necessary not only to understand energy-consuming technologies but also energy-consuming behaviours. Compared to energy efficient technologies, knowledge as to how home occupants consume energy in their residences could be improved (Gaffigan, 2008; Sovacool, 2014). This lack of knowledge of energy behaviours is partly caused by how comfort is understood in the indoor environmental quality field (IEQ) and how comfort-offering technologies are developed (Majcen, Itard, & Visscher, 2013).

IEQ has traditionally been investigated from a technology-driven approach, with a focus on the building, its characteristics, and the physical environment. This process has been done by establishing and following standards and guidelines based on the appropriate amounts (dosages) of stressors to maintain an arguably healthy and comfortable environment for any occupant (Bluyssen, 2009, 2014). Research has shown that comfort is a multidimensional concept not limited to the four individual IEQ factors, but should rather be considered as a psychobehavioral phenomenon instead of limiting it to a perceptual one (Hong, D'Oca, Turner, & Taylor-Lange, 2015; Hong, Taylor-Lange, D'Oca, Yan, & Corgnati, 2016; Ortiz, Kurvers, & Bluyssen, 2017).

On the other hand, building systems, installations, and appliances are researched and developed in such a way that they will satisfy the IEQ standards and guidelines, in an energy efficient manner. Yet, despite the technological developments, energy consumption is not decreasing at the rate it should for the EU 2020 and 2030 targets (Tsemekidi Tzeiranaki et al., 2019). Although factors affecting energy consumption are complex, one that seems to be particularly influential are the occupants' home comfort-making behaviours. Several behaviours at home are exercised to achieve comfort and several of these activities consume electricity or gas (Aune, Ryghaug, & Godbolt, 2011; Ortiz and Bluyssen, 2018; Ortiz, et al., 2017). Consequently, it is important to investigate such behaviours but also the motivations and intentions behind them.

Ortiz and Bluyssen (2018 and 2019) performed a past study that aimed at understanding such motivations. The authors developed a questionnaire to better understand personal differences of comfort-making behaviours and the influence of those behaviours in energy consumption (Ortiz and Bluyssen, 2018).

The present study complements those results with further qualitative data. Specifically, the aim of this study is to find the home occupants' 'interpretive knowledge' regarding comfort and energy use in their homes. The objective of eliciting this type of knowledge is to further complete and improve the previously found archetypes with qualitative data. Particularly with data from their more concealed needs, as opposed to process knowledge data that was elicited in the interviews of the previous study.

Interpretive knowledge is a type of knowledge that is gained in functional contexts and is shaped by the subjectivity of the person experiencing the contexts. In other words, it is the way in which a person interprets experiences and the objects of experiences, through their emotions and intuitions (Bogner, Littig, & Menz, 2009). An effective way of tapping into interpretive knowledge is with the use of generative techniques. Generative techniques are methods in which participants generate artefacts through the aid of visual stimuli. By avoiding initial verbal explanations –such as in interviews- generative techniques allow expressing knowledge that is more difficult to express. Figure 5.1 shows the way in which data from a certain type of knowledge can be gathered.

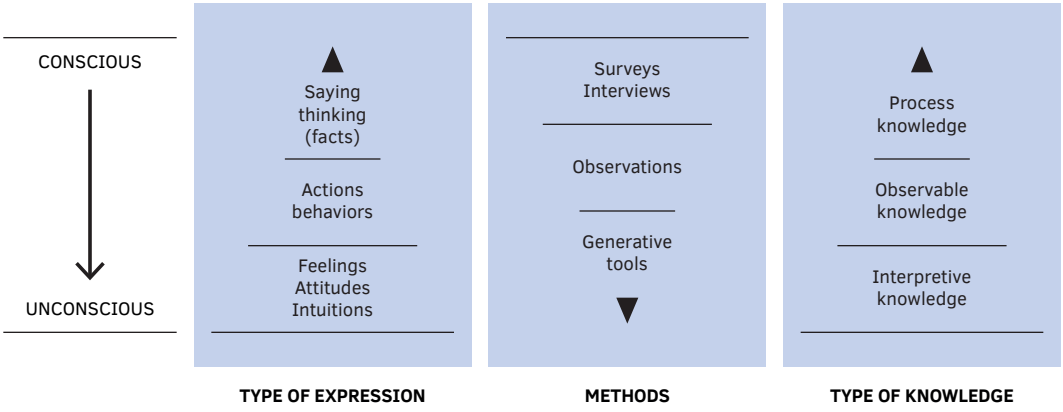


FIG. 5.1 Knowledge levels and respective eliciting methods (adapted from (Bogner et al., 2009; Visser et al., 2005)).

The study performed by Ortiz and Bluyssen (2018 and 2019) involved a questionnaire to assess the psychological motivations behind comfort behaviours of home occupants. The variables comprising the questionnaire evaluated the constructs of emotions towards their home environment, locus of control in their home, comfort affordances (home features needed for the occupant to create comfort), and attitudes towards energy. 761 participants responded to the

TOC

questionnaire and the data was analysed with the TwoStep cluster method. The method groups respondents into similar responses and produces an output in the form of clusters (Norušis, 2012). Five statistical clusters were determined, which were then substantiated with the data from a field study (Ortiz and Bluyssen, 2019). In this field study fifteen of the questionnaire respondents were interviewed, the IEQ parameters of their home were measured, an energy-related building checklist of their home was filled out, and actual energy readings were taken. The results were integrated to those of the clustering analysis to complete the clusters and to create archetypes. The final archetypes that were found in that previous study were named as follows (Table 5.1): Restrained Conventionals, Incautious Realists, Positive Savers, Sensitive Wasters, and Vulnerable Pessimists (Ortiz and Bluyssen 2019).

TABLE 5.1 Key archetypal characteristics according to cluster analysis and field study.

Archetype 1	**Restrained conventionals**	Questionnaire data	– Low positive emotions, high negative emotions – High external control, and low internal control – Medium sensitivity
		Field study data	– Second highest saver – Positive sentiments of energy, control, comfort, but neutral about affordance needs
Archetype 2	**Incautious realists**	Questionnaire data	– Low positive emotions and highest negative ones. – High external control and lowest internal control – Doesn't care about affordances
		Field study data	– Second highest waster – Negative sentiments about comfort, positive about energy, affordances, and control
Archetype 3	**Positive savers**	Questionnaire data	– Second Highest positive emotions and lowest negative emotions. – Lowest external control, and high internal control – Slight affordance indifference
		Field study data	– Highest energy saver – Positive sentiments about affordances and comfort, negative about energy and control
Archetype 4	**Sensitive wasters**	Questionnaire data	– Highest positive emotions, second lowest negative emotions – Low external control, and highest internal control – Affordances are very important
		Field study data	– Highest waster of all – Negative about energy, ambivalent about affordances, and positive about control and general comfort
Archetype 5	**Vulnerable pessimists**	Questionnaire data	– Lowest positive emotions, high negative emotions. – Highest external control, low internal control – Affordances are not important
		Field study data	– Third highest waster – Positive about comfort and control, ambivalent of energy and affordances

5.2 Materials and Methods

Although several definitions exist for the term 'focus groups', depending on each field, in this project, the term focus group will be used for the sessions with projective techniques carried out in this study. The reason for this is because it has sometimes been used an umbrella term for activities where a group of people whose point of view are gathered; in which a moderator has prepared questions and probes to induce participants'' answers; and whose goal is to elicit perceptions, feelings, and attitudes of the participants about the selected topic (Vaugh et al., 1996).

To tap into the interpretive knowledge, focus groups were developed with projective activities. Projective activities are tools drawn from techniques used in clinical psychology (Boddy, 2007). The objective of these techniques is to bypass conscious defences and gather the tacit knowledge; therefore, the participants can provide unchanged views of their feelings and attitudes, which is not possible with more direct questioning. For the creative process, these techniques have been used as they enable researchers to gain information that would otherwise be filtered through the participants' social desirability bias (Boddy, 2007; Hibbard, 2003).

5.2.1 Participant selection

Participants in this study were selected from the respondents who had taken part in the proof-of-concept study (Ortiz and Bluyssen 2018). From October 2016 to October 2017, links to a survey were sent to different types of participants. Respondents volunteered to participate in the focus groups as a follow-up to the questionnaire by providing their email addresses. Seventeen participants consisting of eight women and nine men were contacted and they took part in the focus groups. Generally, they were in their last year of their masters studies and a few were in their bachelors. Ages ranged between 22 and 31 and they resided in Rotterdam, Delft, and The Hague in the Netherlands.

5.2.2 Procedure

As suggested by Visser, Stappers, Van der Lugt, & Sanders (2005), we divided the focus group study into a sequence of three research phases: sensitization, sessions, and analysis. Sensitization is a process that gradually immerses the participants

into the topics of the focus group. According to Visser, et al. (2005) sensitization triggers the participants to start reflecting, cogitating, pondering, and exploring features of their personal experiences in their own environment. In order to achieve this, the sensitizing package that contained a booklet, pencils, markers, stickers with words, and an information sheet explaining the goal and purpose of the research was distributed to the participants one week before their corresponding sessions. The booklet (refer to Appendix E) contained seven short daily activities to ease them into the context: introduction about themselves, word associations with comfort, three-day activity diary, and 'memory-work' writing activity; in which they wrote about their most significant stress-free related memory. The objective of this phase is to let participants start accessing their experiences about topics that they normally do not think about, so that the quality of the data produced during the sessions is wider and deeper.

The sessions took place in the Multisense Lab in the faculty of Industrial Design Engineering of Technical University of Delft from November 2018 to December 2018. The Multisense Lab consists of an observation room and a control room.
The observation room is equipped with microphones, cameras, and a one-way mirror (to the control room), which allowed facilitator to record the sessions and take observation notes from the control room (see Figure 5.2).

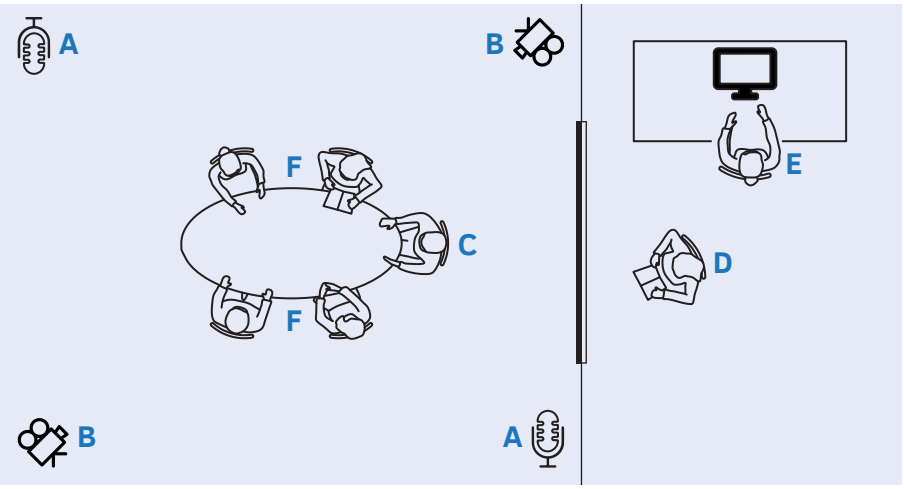


FIG. 5.2 The floor plan of the Multisense lab: observation room and the control room (A: microphones, B: cameras, C: moderator, D: observer in one-sided mirror, E: camera controller, F: participants).

TOC

A facilitator with prior experience in focus groups moderated the sessions. Two more researchers were taking notes and controlling the technical aspects of the session from the control room (camera panning, zooming, volume setting, time tracking), which was connected via the one-way mirror. As Table 5.2 shows, each session lasted approximately one hour and half. The duration of each task was checked by a pilot session with researchers from the Chair Indoor Environment. Before the session started, all participants were given a consent form to sign, informing them about the recording of the session and that if they felt uncomfortable, they could cease their participation.

During the sessions, participants were asked to produce two separate collages: (1) 'Meaning of energy use at home' and (2) 'Ideal home Experience'. Collages were chosen as a method that allows participants to express experiences through pictures and words, rather than verbalizing them. The method is particularly effective in eliciting interpretive knowledge (Hanington, 2007; Sanders and William, 2003).

TABLE 5.2 Timetable of the Group session

Timespan [in minutes]	Activity	Details
0 – 5	Introduction	– Explaining set-up session, goals and emphasizing that they are experts of their own experiences.
5 – 25 (4 per participants)	Warm-up – story/thoughts	– Participants introduce themselves and the booklet story.
25 – 30	Introduction to collages	– Explanations of what collages are, their purpose. Providing materials.
30 – 50	Meaning of energy use at home	– Production of collage of the Meaning of Energy Use.
50 – 60 (2 per participants)	Presentation	– Each person explains and presents the artefacts.
60 – 70	Break	– Snacks and refreshments. – Arranging table and materials for next exercise.
70 – 90	'Ideal home Experience'	– Produce collage of an 'ideal home experience.'
90 – 100	Presentation	– Each person explains the artefacts.
100 – 105	Wrap-up	– Thank you and final remarks

Participants were provided with a collection of photos, pictures, newspapers, magazines, journals, and materials for joining and linking (Velcro, glue, staples, tape); colours, markers, glittery tape, coloured and corrugated cardboard, chenille, sticky notes, differently shaped stickers, and felt. The materials were the same or similar for each of the sessions. For each collage activity in the same session, a different package of materials was provided, to not repeat the stimuli. Magazines with indoors or home pictures were avoided to prevent from leading the participants into certain ways of thinking. Participants were given an A3-cardboard canvas on

which to create the collage. The instructions were given as follows: 'Here are various materials and visual stimuli. Try to use them in any way you want to express what it means to you to use energy at home / what the ideal home experience for you is. You have up to 20 minutes. Please do not talk with the other participants during the activity.' If participants requested to have extra time, it was granted. Participants were given maximum freedom, the moderator only stayed in the room during the first and last 3 minutes of the activity; the rest of the time, the moderator observed the participants from the observation room. If participants seemed stuck or had questions, the moderator would return to the session room to clarify.

The study was reviewed and approved by the ethics approval committee of the Technical University of Delft.

5.2.3 Data analysis

After each session, a diverse range of qualitative data was collected: verbal protocol (audio and video) and artefacts (collages). The collages corresponded to stories, tales, and narratives related to comfort at home and the meaning of energy use. As a result, collages and verbal protocol were qualitatively analysed together as: a) verbal protocol and b) artefact analysis in a seven-step process (Figure 5.3).

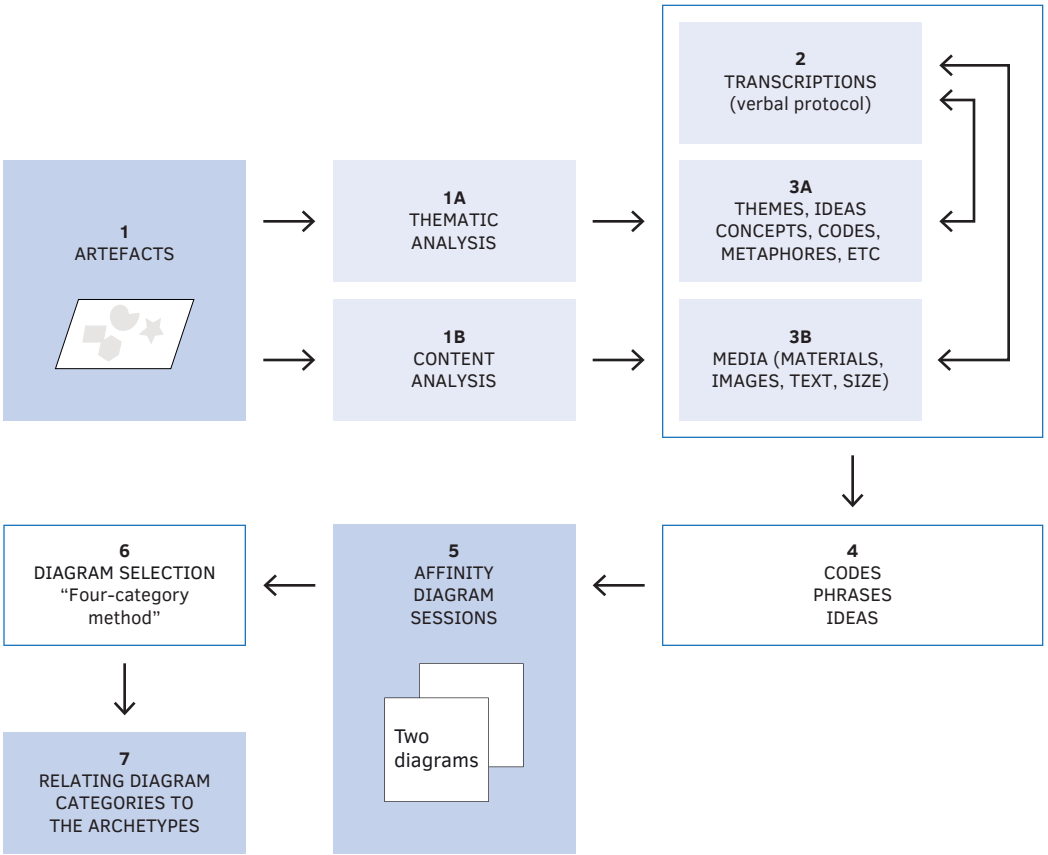


FIG. 5.3 Seven-step analysis process.

5.2.3.1 Transcriptions

First, an investigator produced verbatim transcriptions from the session speeches. This was performed by one researcher playing back the recordings and manually transcribing every word of the transcripts, the timing, and the speaker. Then each collage explanation was analysed according to Polkinghorne and Arnold (2014) by using the recursive abstraction approach (Hershkowitz, Schwarz, & Dreyfus, 2001; Polkinghorne and Arnold, 2014). This technique allows reducing and condensing the verbal data into codes, phrases, and ideas, giving the possibility of identifying patterns within the data that would otherwise not be easy to identify.

TOC

5.2.3.2 Content and thematic analysis

The collages were analysed with the content and thematic analysis approaches (Crowe, Inder, & Porter, 2015; Vaismoradi, Turunen, & Bondas, 2013). This was done with two researchers: the main investigator and another researcher, by observing the collage, measuring the pictures, and deliberating in the codes to be used for content and theme.

Both content and thematic approaches are suitable to analyse exploratory data in fields in which information is scarce (Vaismoradi, et al., 2013). The content analysis is a descriptive and quantifying analysis of the artefact, while the thematic analysis takes an interpretive and qualifying angle. The content analysis shows what type of materials, media, and physical visual objects the participant chose to express his or her experiences. The thematic analysis is done in conjunction with the transcriptions, and it allows understanding the symbolic meaning, concepts, feelings, experiences, ideas, stories and themes, that the participant is expressing (E. Sanders and William, 2003; E. B. N. Sanders and Stappers, 2008; Stappers and Sanders, 2003).

To conduct the content analysis, every element of each collage was thoroughly described by dividing the description into four parts as shown in Table 5.3.

TABLE 5.3 Content analysis description

Content Analysis	Characteristics
Media used on the collage	Materials, images, written text, shapes
Position, Size and Shape.	Size of the objects, position on canvas
Description of image	Description of what the object is
Category of the description	What type of thing is objectively shown (i.e. nature, humans, food, etc.)

Subsequently, the thematic analysis was performed in a similar fashion, per object on the collage. The parts extracted in the thematic analysis are shown in Table 5.4. Once the content and thematic analyses were finalized, two pieces of data were used for the subsequent step: the words and phrases under the ‘theme or idea represented’ and the ‘participant explanations’. These were transferred into a spreadsheet, and combined with the codes of the recursive abstraction from the transcripts of the verbal protocol. This spreadsheet was a list of codes, phrases, and ideas, reflecting the participants’ experiences, and they were used as tags for the next part of the analysis.

TABLE 5.4 Thematic analysis description

Thematic Analysis	Characteristics
Theme or idea represented	Main theme or idea as the participant explained of the object
Processes represented	Processes represented by the object
Metaphors or symbols	Whether the object is a symbol for another concept
Participant explanations (with transcripts)	Verbatim excerpts of transcripts for each object

5.2.3.3 Affinity diagrams

As mentioned before, the codes are words drawn from the themes of the thematic analysis. When the codes are produced, they are made into physical tags to create affinity diagrams. An affinity diagram is a tool that allows organizing large numbers of qualitative ideas and data into groups in order to see the natural relations between pieces of data pertaining to two or more topics; in this case, the meaning of using energy at home and the ideal home comfort experience.

Two sessions were required to produce a final diagram with the final categories. The first session involved five researchers unrelated to the research to create the code patterns. The second session involved four researchers, that did not take part in the first session and that were also unrelated to the project. Both sessions were supervised by the main investigator, who guided but did not give inputs. In order to select one of the two diagrams for further inspection, the 'four-category method' was used as described by the Interaction Design Foundation (Dam and Siang, 2018). This method requires the two resulting diagrams to be rated based on objectivity and concreteness, to avoid unrealistic or improbable categories. This is done by rating the diagrams categories and sub-categories with a 4-point scale from the least concrete to the most concrete. The diagram of the first session was chosen as it had categories that are more concrete.

Finally, the factors of the affinity diagram were associated to the archetypes to which the participants belonged. This was done by referring the individual pieces of data making up the affinity diagram's sub-categories back to the contents of each of the artefacts.

Table 5.5 presents an overview of the three research phases in this study, along with their purpose, methods, materials, and other characteristics.

TABLE 5.5 Three research phases in this study.

	Sensitization	Sessions	Analysis
Purpose	Enable participants to access their experiences about topics that they do not normally think about in order to enrich the quality of their data from the sessions.	To obtain participants' interpretive knowledge of 'Meaning of energy use at home' and 'Ideal home experience'	To interpret qualitative data obtained from the recorded audio and from the collages and to link to the five archetypes.
Method	Conducting short daily activities for seven days (see Appendix E)	Production of two collages (A3 size) per participant and verbal explanations of their productions (see Appendix F & G)	Transcriptions, Content analysis, Thematic analysis and affinity diagrams
Materials	A booklet, pencils, makers, stickers with words and an information sheet	A collection of photos, pictures, newspapers, magazines, journals, and stationaries	
Duration	1 week	Approximately an hour and a half (see Table 5.2 for more details)	
Location	No particular location was set (preferably at home)	An observation room of the Multisense Lab at TU Delft (See Figure 5.2)	
Timeline	Started 1 week prior to their corresponding sessions	November 2018 to December 2018	

5.3 Results

5.3.1 Thematic Analysis

Thematic analysis yielded 74 codes in the 'ideal home experience' topic, while the most common factors amongst all of the archetypes were 'nature', 'social interaction', 'connectedness', 'food', 'safety', 'space', 'furniture' and 'freedom'. For the 'meaning of energy use at home', there were 58 codes for all participants. Tables 5.6 and 5.7 show the ten recurring codes for each archetype for 'the meaning of energy use at home' and 'the ideal home experience', respectively. The tables suggest that archetypes have different mental models regarding the two topics, in terms of what they value higher for such topics. However, it can be seen that there are still collectively shared values and needs, especially in terms of nature, energy, comfort, and control.

TABLE 5.6 Percentage frequency of ten most recurring codes for 'meaning of energy use at home' per archetype.

Archetype 1		Archetype 2		Archetype 3		Archetype 4		Archetype 5	
Restrained conventionals		Incautious realists		Positive savers		Sensitive wasters		Vulnerable pessimists	
Code	%	Code	%	Code	%	Code	%	Code	%
Nature (conserving)	9.3	Energy	9.6	Lack of control	17.4	Energy	9.5	Lights	5.9
Forces of nature	8.0	Scale (large)	5.2	Lost	13.0	Costs	7.1	Relaxing	5.2
energy	6.7	Comfort	4.3	Control	13.0	Controlling	7.1	Entertainment	5.2
Saving planet	5.3	Waste	3.5	Awareness	13.0	Comfort	7.1	Energy	4.4
Water use	4.0	Use	3.5	Powerlessness	8.7	Sustainability	4.8	Breeze	4.4
Time	4.0	Future	3.5	Chaos	8.7	Discomfort	4.8	Wasting	3.7
Feeling	4.0	Worry	2.6	Watching	4.3	Wrong	4.8	Nature	3.0
Environment	4.0	Nature	2.6	Taking care	4.3	Warming	2.4	Water	2.2
Battle	4.0	Electricity	2.6	Caring	4.3	Turn	2.4	Using	2.2
Watched (being)	2.7	Vision	1.7	Action	4.3	Quick pleasure	2.4	Night	2.2

TABLE 5.7 Percentage frequency of ten most recurring codes for 'meaning of energy use at home' per archetype.

Archetype 1		Archetype 2		Archetype 3		Archetype 4		Archetype 5	
Restrained conventionals		Incautious realists		Positive savers		Sensitive wasters		Vulnerable pessimists	
Code	%	Code	%	Code	%	Code	%	Code	%
nature	10.8	nature	8.2	view	9.7	privacy	7.7	nature	8.4
Rest	6.2	freedom	4.9	minimalism	9.7	spacious	5.8	connectedness	5.0
food	6.2	space	4.1	urban	6.5	furniture	5.8	love	3.4
cosy	6.2	social	4.1	sharpness	6.5	artistic	5.8	colours	3.4
aesthetics	6.2	interaction	4.1	investment	6.5	worriless	3.8	automation	3.4
interaction	4.6	small	3.3	industrial	6.5	Travel potential	3.8	Social interactions	2.5
furniture	4.6	food	3.3	Connectedness	6.5	sustainable	3.8	pets	2.5
entertainment	4.6	closeness	3.3	central	6.5	Stress-free	3.8	Water natural	1.7
connectedness	4.6	water	2.5	artistic	6.5	safety	3.8	sustainable	1.7
social	3.1	safety	2.5	vegetables	3.2	relax	3.8	stargazing	1.7

5.3.2 Affinity diagram categories

The affinity diagram (Figure 5.4) produced two categories: the occupant-related category (divided into behavioural sub-categories and psychological sub-categories) and the building-related category (sub-divided into home sub-categories, financial aspects, and energy sub-categories). In total there are 24 factors making up the sub-categories. One 'uncategorized' factor was also included with codes that did not belong to any of the sub-categories.

Charts were produced for the two topics of the collages. Figure 5.5 shows how frequently a code belongs to an archetype for the 'Meaning of energy use at home' and Figure 5.6 shows it for the 'Ideal home experience'. They show the percentages that a code, phrase, or idea is mentioned by an archetype: the frequency (percentage) is interpreted as the meaningfulness or the need of the theme for the specific archetype.

Figure 5.5 shows when using energy at home, archetype 1 expressed experiences mainly related to the factors personal space, neutral energy concepts, and having positive emotions in their homes. Archetype 2's main concerns are related to factors of aesthetics, location, and feeling safe. The highlights of the experience of archetype 3 in regards of energy use concern factors of cleanliness, maintaining control, and doing activities in the home. Archetype 4's meaningfulness lies in experiences regarding factors of control, using the lights, and a concern for wasting energy. Finally, Archetype 5 expressed mainly ideas concerning factors of social interaction, lifestyle principles, and the use of lights as highlights when using energy.

For the 'Ideal Home Experience' (Figure 5.6), the factors of home aspects are important for Archetype 2; 3; and 5. Specifically, archetype 5 shows highlights with 'home features and décor', 'aesthetics', 'contact with nature', and 'size and layout'. Archetype 2 finds important 'areas and zones', 'lights', and 'size and layout'. Archetype 3 expressed value in the 'location of the home' and a need for 'outside view'. Archetype 4 values 'softness' and 'outside view' and Archetype 1 values the same ones. Archetypes 3, 2, and 1, regard the financial aspect with an important role in the ideal home experience.

In energy aspects, archetype 5 has technology as an important need for an ideal home experience, as well as having renewable energy sources. Archetype 2 is concerned with the drawbacks of using energy, and Archetype 4 would prefer to have renewable energy sources.

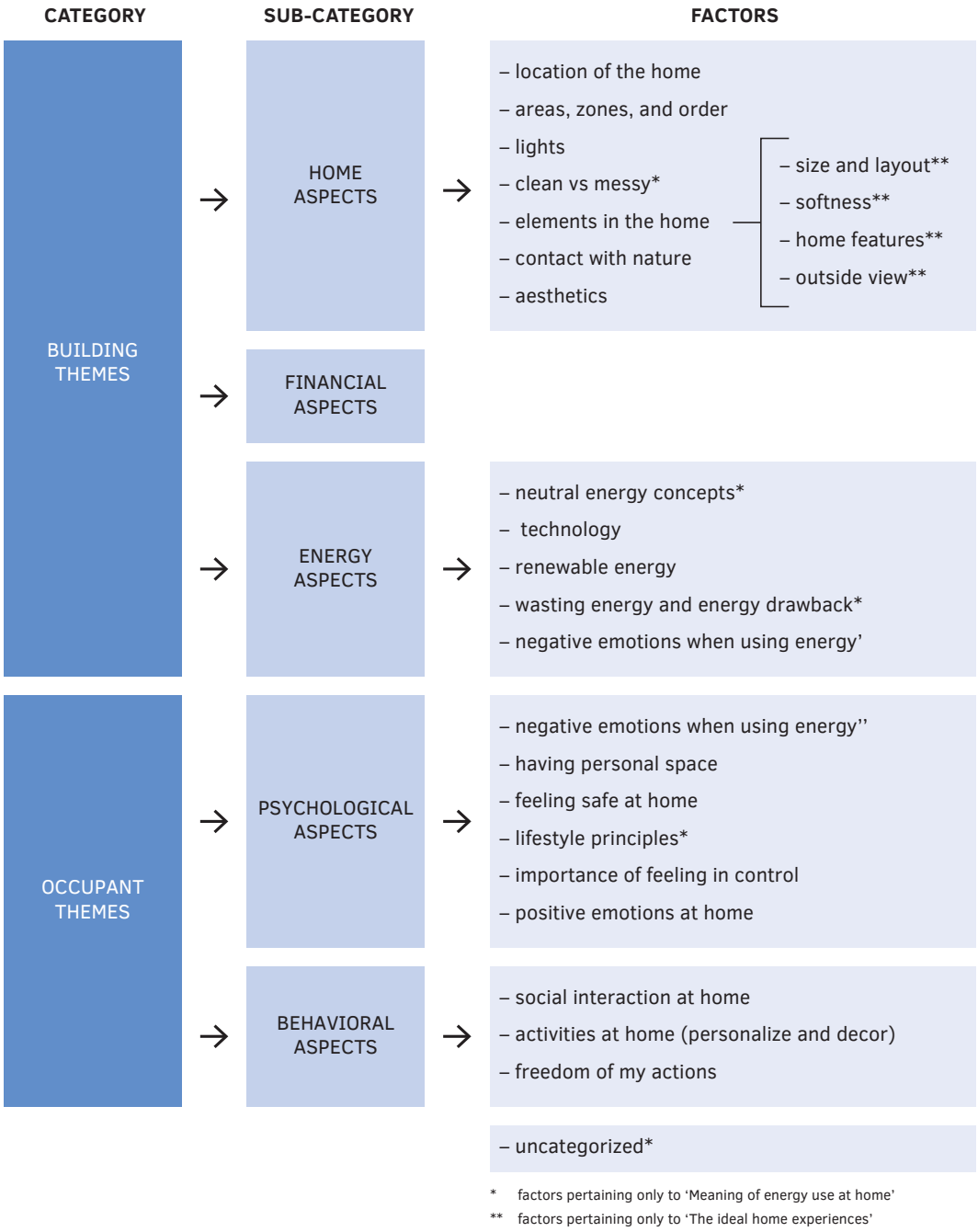


FIG. 5.4 Categories, sub-categories, and factors of affinity diagram.

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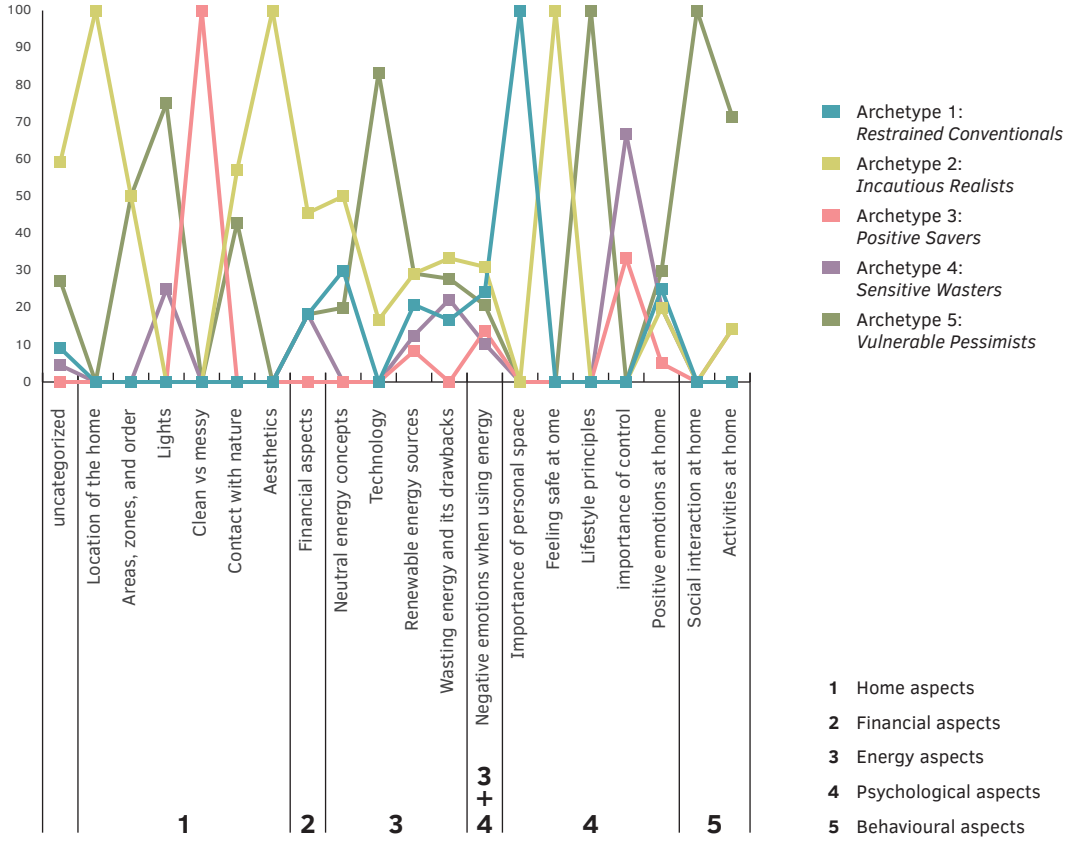


FIG. 5.5 Results 'Meaning of energy use at home'

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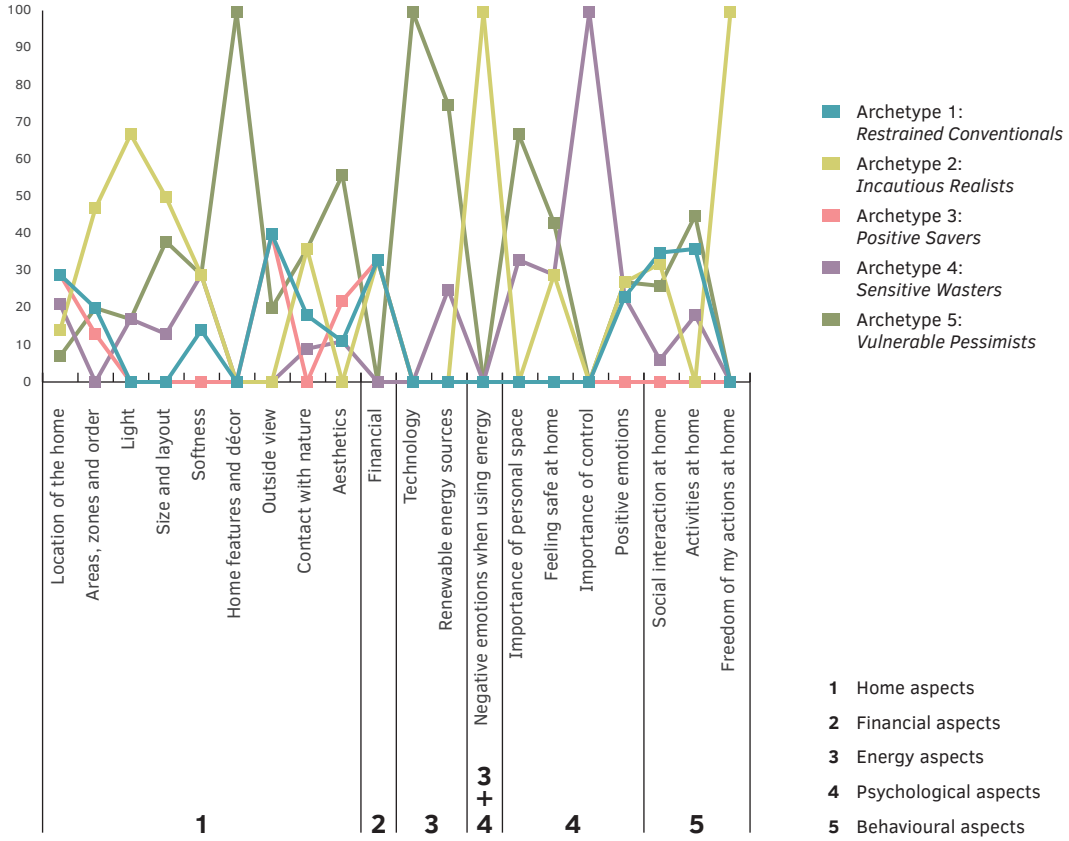


FIG. 5.6 Results 'Ideal Home Experience'

For the psychological aspects, archetype 4 expressed the importance of feeling in control, personal space, and safety. Archetype 2 regards safety highly, and all archetypes want to have positive emotions in their future homes. For the behavioural aspects, Archetype 2 needs freedom of actions, and Archetype 1; 4; and 5, need to be able to do the activities they like, like hobbies.

Supporting figures 5.5 and 5.6, is Table 5.8 presenting for each archetype the main factor of importance for each of the five subcategories (home aspects, financial aspects, energy aspects, psychological aspects, and behavioural aspects) in terms of their combined home experience (using energy and ideal situation).

TOC

TABLE 5.8 Number one factor per archetype for the five subcategories

Subcategory / Archetype		Home	Financial	Psychological	Behavioural	Energy
Archetype 1	Restrained conventionals	Outside view	Medium concern	Importance of personal space	Importance of social interaction	Neutral energy concepts
Archetype 2	Incautious realists	Size and layout	High concern	Feeling safe at home	Freedom of my actions	Neutral energy concepts
Archetype 3	Positive savers	Cleanliness and orderliness	Not concerned	Importance of feeling in control	Activities at home	Renewable energy sources
Archetype 4	Sensitive wasters	Softness	Low concern	Importance of feeling in control	Activities at home	Wasting energy and its drawbacks
Archetype 5	Vulnerable pessimists	Home features and décor	Low concern	Home matching one's lifestyle principles	Activities at home	Using technologies

5.4 Discussion

5.4.1 Implications and relevance

Generative techniques are a useful method to gain knowledge from users that would otherwise not be possible to elicit through questionnaires or interviews. As is the case with qualitative techniques, large amounts of data are produced, and need to be processed pertinently. The value of analysing the data with the affinity diagram technique is that it allows assimilating large amounts of qualitative data produced in the focus groups and to see new patterns and groups. Some of the connections that appeared are the following: 15 of the 25 factors overlap between the two topics (location of home; areas, zones, order; lights; contact with nature; aesthetics; financial aspects; technology; renewable energy; negative emotions when using energy; importance of personal space; feeling safe at home; importance of control; positive emotions at home; social interactions at home; and activities at home). The factors that only pertain to the meaning of energy use at home are 'neutral energy concepts'; 'wasting energy and energy drawbacks', 'lifestyle principles', 'cleanliness and messiness'. While the factors that only belong to the 'ideal home experiences' are: elements of the home (comprising size and layout, softness, home features, and outside view), and freedom of my actions at home.

Building upon the questionnaire results and the field study results from Ortiz and Bluyssen (2019), where text mining from interviews, environmental monitoring, actual energy use readings, and building characteristics checklists were performed, and the results of the generative techniques, the following archetypes are presented:

Restrained Conventionals (archetype 1) are the largest archetype as of the results of the cluster analysis. In this study, they relate the meaning of energy use at home particularly to the drawback of wasting energy and the negative emotions when using energy, and the fact that the use of energy is done at the expense of nature and the environment. In the second collage of the 'ideal home experience', they expressed three main needs for the future: social interaction, contact with nature, and being able to do certain activities at home. In the previous study, they reported higher-than-average positive emotions, high external control, and low internal control; while expressing positive attitudes about energy and sense of control during the interviews, but neutrality about comfort needs. Energy reading averages showed that they are the second largest saver.

Incautious Realists (archetype 2) described their experience mainly with 'neutral energy concepts' and they tend to focus into the future of energy use by observing future possibilities of cleaner energy. For the ideal home experience, their main ideal future need is a home with contact with nature, in which social interaction is possible, and with the right size and layout. In the previous study, the outcomes show that they have high negative emotions about their homes; they score lowest in internal control, and high in external control. Yet, during interviews, they expressed positive attitudes for affordances and psychobehavioral topics of home comfort (using appliances, feeling in control). On average, the energy readings showed that they are the second largest wasters.

Positive Savers (archetype 3) recall mainly the negative emotions about using energy, but also propose that using renewables can bring a more positive experience. Furthermore, for the ideal home experience, they put more emphasis in a need for aesthetics of the home and the location in which it is found. In the questionnaire study, it is shown that they have the second highest ratings for positive emotions and lowest in negative; lowest external control and second highest internal. In interviews, they expressed positive attitudes for affordances, and negative ones about comfort and energy. Energy readings reflect them as the least consuming of all groups.

The Sensitive Wasters' (archetype 4), past experience deals mainly with the drawbacks of wasting energy and with the financial side of using energy. For the ideal home, they have a higher value for feeling positive emotions in general in their future home, which should also be a place where they have their own privacy.

According to the previous study, they have the highest scores in positive emotions and second lowest in negative ones. Similarly, they have the highest internal control and the second lowest external control. In the interviews, they expressed positive opinions about comfort and control of the environment but negative ones on energy awareness. Readings show them as the highest energy consumers of all the archetypes.

Finally, Vulnerable Pessimists (archetype 5) generally express that using technologies in the home is the main experience of energy use and, that such technologies allow for improved standards of living. Their principal needs are to own a home where they have contact with nature and that allows for social interaction. They have, according to the cluster analysis, the lowest scores in positive emotions about the home, and second highest negative emotions. They also present the highest external control and second lowest scores in internal one. Interviewees generally expressed emotional ambivalence in energy awareness, control of environment, and affordances, but positive emotions with general comfort. According to their energy readings, they are the third largest waster.

5.4.2 Practical significance

The archetypes can be used in the energy-engineering field for improved and more accurate simulation and building prediction models and outcomes. Furthermore, the occupants pertaining to a certain archetype can be invited to take part in co-creation sessions in the design process of systems, appliances, or interfaces, to design possible custom-made products or environmental features for each archetype. In other words, the specific characteristics of an archetype can be translated into design parameters (interfaces, products) that will support their mental models in a more energy-efficient fashion. This would then enable developing customized products or interfaces that will offer a more personalized comfort while saving energy. For the development of such user-centered products or systems, further analyses are needed such as brainstorming sessions, concept formulation, prototype building, etc. and eventually user-testing and iterative improvements the concepts to arrive to final designs customized for the archetype.

Finally, models pairing archetypes with specific environmental characteristics can prove interesting for architects, contractors, engineers, or housing associations in order to provide the specific archetype with the adequate features that will support efficient behaviours, while maintaining customized comfort.

5.4.3 Strengths and limitations

One limitation of this study is that due to the number of participants, the results should be interpreted as case studies, rather than as representative of each archetype. Another limitation is the fact that all focus group participants were students and with no large age variations: for such a study, it would be ideal to recruit different types of people from each archetype. In general, limitations that can occur in this type of research are the following. Although the technique is powerful and can produce invaluable data that cannot be accessed with any other method, it has also the risk of not producing the depth of data. Instead, shallow data can be obtained. Such a risk exists, particularly if the participants have not been sensitized to the topic beforehand. This can also occur if the participants do not feel at ease during the session and ready to share their emotional experiences with strangers or the moderators.

5.5 Conclusion

This is, to the knowledge of the authors, the first attempt to investigate the energy use at home and its relation to comfort, by using focus groups -and more specifically generative techniques- in a qualitative way.

In the previous study, in which archetypes were developed, a questionnaire assessed constructs related to emotions, control, needs from a psychobehavioral perspective to create statistical clusters. Further, the results of another study -in which some of the archetypes were interviewed- improved those clusters, by eliciting their procedural knowledge –know-how knowledge. Along with this data, building data, IEQ data, and energy data were also collected and were part of the substantiation of the clusters.

This study sheds lights on how generative techniques can be a valuable tool for delving into the interpretive knowledge –the why's- of the behaviours and mental models of home occupants' past experiences and potential future wishes in terms of comfort and energy use. The study also shows how different home occupant archetypes have clearly distinct needs and how they give different meaningfulness to past experiences of using energy in their homes and to what an ideal home experience is. In particular, this data is valuable to complement quantitiave data to

strengthen home occupant archetypes. The aim of improving quantitative archetypes with qualitative data regarding energy and comfort, is to ultimately help engineers, architects, and designers to develop technologies that will support the archetypes' behavioural patterns, so that energy consumption reduction can be achieved, while maintaining or improving comfort and health levels.

The results of the present study show that each of the five archetypes has different mental models, different needs in terms of comfort, expectations, and different ways of understanding energy in their own homes. The findings of this study specifically show that for energy aspects, Sensitive wasters (Archetype 4) is concerned about wasting energy, Vulnerable pessimists (Archetype 5) about the technologies surrounding energy, while Incautious realists (Archetypes 2) and Restrained Conventionals (archetype 1) are neutral, and Positive savers (archetype 3) is focused on renewable sources. For behavioural aspects, freedom of action is important for Incautious realists (Archetype 2), while Sensitive wasters (Archetype 4) values social interaction and the rest of the archetypes put importance on the activities carried out at home. Psychological aspects, Vulnerable pessimists (archetype 5) values their lifestyle principles, Sensitive wasters (archetype 4) and Positive savers (archetype 3) having sense of control, Incautious realists (Archetype 2) finds feeling safe important, and Restrained Conventionals (archetype 1) needs personal space. In the home aspects category, Restrained Conventionals (archetype 1) needs view to the outside; Incautious realists (archetype 2) needs right size and layout, Positive savers (archetype 3) about cleanliness, Sensitive wasters (archetype 4) about softness of materials, and Vulnerable pessimists (archetype 5) about décor. Finally, only Restrained Conventionals (archetypes 1) and Incautious realists (archetype 2) find finances important. Understanding this information is a first step to implement lines of action at home or to design interventions tailored to the archetypes understanding of energy and needs of comfort.

Finally, the use of generative techniques, in particular that of collages, seems to have been an appropriate technique; a technique that is normally used in the field of user-centered design, in order to better understand users' mental models. With the data gathered in this study, along the one collected in the previous studies, and with further analyses, it is possible to develop design concepts for each archetype, to offer them products that will satisfy their comfort needs while supporting their specific behavioural patterns.

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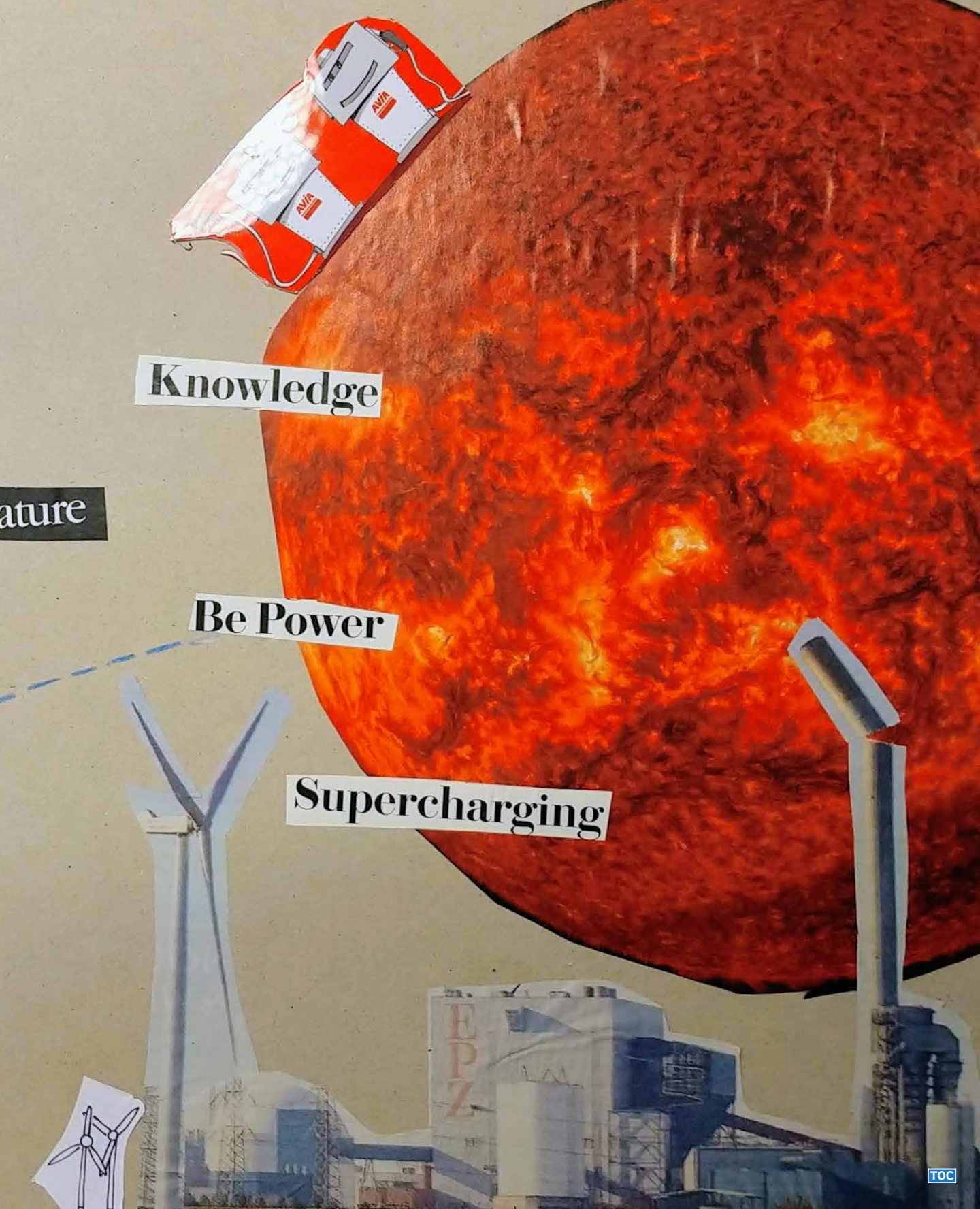
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6 Conclusion and recommendations

6.1 Introduction

This research provided insights into the comfort and energy-consuming behaviours of home occupants and into grouping these home occupants based on their individual differences. This was achieved by using a human-centered approach to an engineering challenge, by assuming comfort as a holistic experience of the home environment, and by treating the 'occupant-environment' interactions as a dynamic system.

Such an approach drew methods typically used in design and ethnographic research, by gathering both qualitative and quantitative data from both the occupant and the building. The occupant data was collected quantitatively with the use of a questionnaire (self-reported) and qualitatively with interviews (procedural knowledge) and finally with generative techniques (interpretive knowledge). In such a way, different types of occupant knowledge were elicited and collected. The building data was gathered with checklists, monitoring, and energy readings.

With the questionnaire data and a clustering technique -the TwoStep cluster analysis- five distinct types of occupant, or archetypes, were discovered and they were progressively enhanced and substantiated with the interview and generative techniques data. Additionally, data of building characteristics, indoor environmental factors, and actual energy consumption completed the details of the archetypes.

The following paragraphs provide the conclusion and recommendations drawn from this research. First each of the key questions are answered followed by the answer to the main research question; in which the final description of the archetypes is presented. This is followed by the strengths and limitations of this work and

recommendations for the future process. Then for each archetype, environmental design parameters are presented. This finishes with recommendations for future research and the implications of this work.

6.2 Answers to the Research questions

6.2.1 Answers to key questions

Part 1 – (see Chapter 2)

- What lies behind behaviour?
- What characterizes habits?
- What is comfort?
- How do home occupants achieve comfort?
- How are comfort behaviours and energy use related in homes?

To answer these questions, an extensive and multidisciplinary literature review was performed, aiming at providing the main ground to identify new methods to study daily energy consumption and its relation to comfort.

Behaviours are actions that an individual exercises to achieve certain goals. These actions are motivated by several factors, ranging from the physical environment, to the social environment, and the psychology and culture of the person. For the study of comfort and energy use, a person-focused approach was explored, specifically with the Theory of Interpersonal Behavior (TIB). The TIB explains that behind any behavioural expression lie the intentions of the individual to perform the behaviour. These intentions are driven by four factors: emotions, attitudes, control, and needs. In simple words, emotions drive a person towards pleasantness and away from stress. Attitudes are appraisals of concepts that affect a person's thoughts and ultimately actions. Control is the degree to which a person believes they can influence their environment or vice versa. Needs are what an individual finds necessary to feel physiologically, socially, or psychologically satisfied. The combination of these constructs culminates in mental models that shape one's behaviours.

TOC

Habits have to be treated independently from regular behaviours, as they are not influenced by the aforementioned constructs. This is because habits occur in a more primitive part of the brain, and as a result, they are semi-unconscious, automatic, repetitive, goal-oriented, and are triggered by stimuli. In this thesis, such habitual actions have been defined as interactions with the technical devices, and thus, that spend energy.

Comfort is described from different disciplines, showing how comfort is a dynamic and fuzzy concept, and it is more complex than the perception of thermal, acoustical, visual stimuli, or air quality environment. The chapter proposes a common definition of comfort: it is a state of homeostasis; a state in which the individual is physically, physiologically, psychologically, and socially neutral.

Humans achieve comfort by interacting and manipulating their environment, and many of such activities result in the consumption of energy (either with the use of electricity or gas). Homeostatic activities were summarized as: cleaning and ordering, warming up, cooling down, ventilating, using lights, cooking, controlling systems, relaxing activities, personalizing activities (décor, furniture), socializing or other freedom activities, control of privacy, changing the mood of spaces, and hobbies.

Part 2 – (see Chapter 3)

- How can home occupants be categorized into “clusters”?

A technique drawn from the user-centered design field was used to find personas or archetypes of occupants. Typically, an archetype is the synthesis of data collected from surveys or interviews with users, describing goals, patterns, skills, attitudes, etc. In this case, a specialized questionnaire to assess the motivations behind comfort and energy-consuming behaviours was developed. In the questionnaire, a total of fifteen items identified in the literature as ‘energy expending’ and ‘homeostasis attaining’ were selected, to assess their habit strength. Further habitual items that were deemed ‘necessary’ rather than homeostatic were included in the interviews for deeper analysis (i.e. showering and length).

The questionnaire assessed the variables related to the homeostatic activities that were identified in the previous chapter. The questionnaire was developed by adapting previously-validated questionnaires to the specific context of this project, namely, energy-consuming comfort-making activities in the home. The adaptation of previous questionnaires was done by adjusting the wording. The questionnaires that were adapted

were the locus of control questionnaire, the PrEmo2 for emotions, the self-report index of habit strength, in addition to using 5-point Likert scales with semantic differentials for the needs and attitudes, based on the theory of planned behaviour guidelines.

The method of analysis is highly dependent on the type of questions or the variables that are asked in the questionnaire. Literature suggests that questionnaire data can be categorized by using a wide range of techniques, such as principal component analysis, discriminant analysis, cluster analysis, correlation analysis, exploratory factor analysis, or factor analysis.

Due to the type of variables making up this questionnaire, the cluster analysis was used, and more specifically the TwoStep cluster analysis. This method allows for the clustering of both categorical and continuous variables.

With the method, six archetypes were found in the proof-of-concept were found. The final model of clusters comprised of variables pertaining to emotions, control, and affordances.

Part 3 – (see Chapter 4)

- How does the indoor environment of different home occupants differ?
- How do the characteristics of their buildings differ?
- How do the different types of occupants differ in their use of energy?
- How do the different types of occupants express themselves about comfort habits, energy, and affordances in their homes?

Once it was determined that the questionnaire and the analysis type worked in a stable way to classify home occupants, the questionnaire was administered to a full sample. With the full sample and the TwoStep cluster analysis, a final model of five distinct archetypes was produced.

However, the clusters from the questionnaire are limited to self-reported data. Additionally, since this thesis follows a user-centered design method in which not only self-reported data is used but also qualitative data, a field study was designed to interview participants and to use that data to complete the clusters. The interviews were analysed with sentiment analysis. Sentiment analysis is a process from the field of computational linguistics that enables identifying and categorizing opinions expressed qualitatively to find if the person expressing such opinions has positive, negative, or neutral attitudes towards a certain topic, in this case, comfort and its context, as defined in this thesis.

For the environmental monitoring, due to the small number of field study participants, it was not possible to determine whether statistically significant differences exist among archetypes, however, by treating the archetypes as case studies, the following results are drawn: for temperature, carbon dioxide, and relative humidity of their preferred location indoors, there are no major differences among archetypes. Specifically, for temperature, a 4-degree difference exists between the coolest and the warmest location, with archetype 2 having the hottest location and archetype 1, the coolest. For CO2 and relative humidity, archetype 2 has also highest readings. Archetype 1 has the lowest CO2 readings, and for RH, archetype 4 has the "driest" environment. These results, because of coming from fifteen dwellings, are not definitive to propose that differences of indoor environment exist amongst archetypes. The same applies for the results of the building features.

For the actual energy consumption, the readings varied greatly among archetypes. From a lowest reading of 81 kWh a month, up to 617 kWh and gas varied from 9 m3 to 624 m3 per month per person. By treating the archetypes as case studies, from least wasting to most wasting, the archetypes can be ranked as 3; 1; 5; 2; and 4.

The sentiment analysis should also be assumed as individual case studies. For the psychobehavioral topics, in general, which include energy awareness, general home comfort, and control, all archetypes had relatively positive attitudes and opinions, except for archetype 3, which had negative ones. For the topics regarding different elements of their home (freedom at home, lights, temperature, smells, cleanliness, noises, privacy, and security), both archetypes 2 and 3 expressed positive attitudes and opinions. However, 1, 4, and 5 were either neutral or ambivalent.

Part 4 - (see Chapter 5)

- How do the occupant profiles differ in their "home comfort experience"?
- How do occupant profiles perceive their own "experience of using energy in their homes"?

A focus group with generative techniques was conducted to answer these questions. Seventeen participants, who had also responded to the questionnaire before, were recruited to take part in the focus group sessions. The focus groups had two generative activities, one for the meaning of energy use at home, and the second for expressing their ideal home experience. The generative techniques were designed with the creation of collages: participants were given materials with visual stimuli to express their feelings about the topics.

The analysis was done by transcribing their explanations and analysing the collages with content and thematic analysis, and eventually by creating affinity diagrams showing the relationships of the data found.

The affinity diagram generated two main categories: building themes and human themes, containing five sub-themes (home, financial, energy, psychological, and behavioural aspects). The analysis shows that per archetype, each one expressed different needs in terms of an ideal home experience as well as different meaningful aspects of experiences of using energy in their homes.

The findings of this study specifically show that for energy aspects, Archetype 4 is concerned about wasting energy, Archetype 5 about the technologies surrounding energy, while Archetypes 2 and 1 are neutral, and archetype 3 is focused on renewable sources. For behavioural aspects, freedom of action is important for Archetype 2, while Archetype 4 values social interaction and the rest of the archetypes put importance on the activities carried out at home. Psychological aspects, Archetype 5 values their lifestyle principles, Archetype 4 and 3 having sense of control, Archetype 2 finds feeling safe important, and Archetype 1 needs personal space. In the home aspects category, Archetype 1 needs a view to the outside; Archetype 2 needs the right size and layout, Archetype 3 values cleanliness, Archetype 4 values softness of materials, and 5 values aesthetics décor. Finally, only Archetypes 1 and 2 find finances important. Understanding this information is a first step to implement lines of action at home or to design interventions tailored to the archetypes understanding of energy and needs of comfort.

6.2.2 Answer to the main question

How can energy behaviours be studied from a comfort-driven perspective in order to facilitate the development of technologies that support more efficient occupant behaviours and that provide the comfort needs of the person?

The methodology used in this thesis was a mixed-methods approach, in which first, the quantitiave data was collected and subsequently the qualitative one was gathered. This sequence tends to be done in fields relatively new to qualitative approaches. The quantitative part of the research involved the administration of the questionnaire, which was developed from the extensive literature review. The results of the questionnaire were the basis for the qualitative part. The overall intent of this design was to have the qualitative data from the interviews and the focus groups explain and complete in better detail the quantitative cluster results by exploring the participants' views and mental models in depth.

The reasoning behind both kinds of data is because neither quantitiave nor qualitative data are enough to explain the trends and specificities of the challenge of comfort and energy behaviours (Ivankova et al. 2006). Yet, when integrating them to complement each other, a richer and stronger outcome can be reached. This project strived for such complementation of quantitative and qualitative strengths. For the qualitative part, it was decided to use interviews first and focus groups second. The reason for this is that each method elicits different types of knowledge: procedural and interpretive.

As this research is based on a human-centered design approach, talking directly with those that are being investigated is important to hear from them their opinions on the topic (IDEO.org, 2015). The interviews were conducted in the participants' own homes to learn about their mind-sets, lifestyle, and behaviours related to energy use and comfort-making. With the interviews, different insights are gained, and with the type analysis, it was learned about their opinions on comfort and comfort behaviours, their homes affordances, and their views on energy use.

The next method involved the focus groups, and specifically asking participants to produce collages. Making collages enables participants to think in other ways about the topic, and especially to express their feelings, values, and thought processes in relation to the use of energy, comfort, and what makes an ideal home (Sanders & Williams, 2002).

Five distinct archetypes were found: the Restrained Conventionals, the Incautious realists, the Positive savers, the Sensitive wasters, and the Vulnerable pessimists.

The Restrained Conventionals are the youngest group (mean age: 25.4 years). They reported to generally have higher-than-average negative emotions, and low positive emotions, while having high external and low internal control. They expressed positive opinions for energy motivations, comfort, and sense of control, but a general ambivalence of opinions about affordances during the interviews. They are the second lowest energy consumer with 366 kwh and 189 m^3 of energy monthly.

The Incautious Realists are the second largest and have a mean age of 27.3 years (SD: 9.3). They have the highest rating of negative emotions, while having low positive emotions. They score lowest in internal locus of control, and higher-than-average external control. Interviewees expressed relative positive opinions about their general affordance and psycho-behavioural topics. They are the second largest waster with 394 kWh and 419 m^3.

The Positive Savers are the oldest cluster (33.9 years). They show the second highest ratings in positive emotions, and lowest for negative emotions. They have the lowest scores in external control, and second highest scores in internal control. In interviews, they expressed very highly positive opinions about affordances and slightly negative ones about comfort and energy. They are the biggest savers with only 81 kWh per month per person on average and 9 m^3 of gas.

The Sensitive Wasters scored the highest in positive emotions, and the second lowest in negative emotions. They have the highest internal control scores and second lowest external control. Interviewees expressed positive opinions about comfort and control of the environment topics but negative ones about energy awareness, while half of their opinions about affordances were positive. They are the highest consumers with 644 kwh of electricity and 557 m^3 of gas.

The Vulnerable Pessimists scored the lowest in positive emotions and second highest in negative emotions, while having the highest external control scores, and second lowest in internal control. They expressed ambivalence on energy awareness, control of environment, and affordances, but positive sentiments with general comfort. They are the third largest waster with 324 kWh and 288 m3 according to energy readings.

To show a ranking of the archetypes in terms of actual energy use and of comfort needs, Figure 6.1 depicts such variables drawn from the results of the questionnaire.

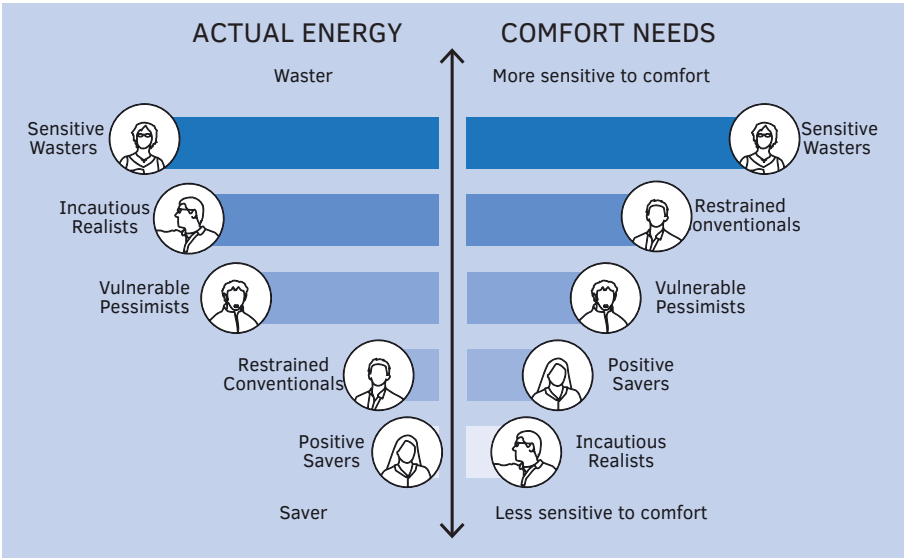


FIG. 6.1 Ranking of Archetypes for energy use and comfort affordance needs.

TOC

The diagram shows the biggest energy waster and the biggest saver, juxtaposed with the archetype that needs more home features to feel comfortable. The diagram proposes that there seems to be a negative relationship between comfort and energy use, which is supported by the idea that, to be comfortable, energy has to be spent.

Finally, the results of the thesis suggest that the mixed-methods approach is a suitable approach to study energy and comfort, as these are fields that normally do not use qualitative data. Clustering the respondents of the questionnaire is a strong basis to build upon to create archetypes. Basing the qualitative methods on human-centered design techniques, with interviews and focus groups, is also an adequate method to study energy and comfort behaviours, because this allows getting to know the lifestyles, opinions, values, and processes in more depth of each of the archetypes and the differences among each other.

The archetypes produced in this work are not only supported by other studies of occupant profiles as shown in chapter 4, but they also show that each of them has different needs to feel comfortable, different behaviours to attain comfort, different attitudes towards energy use, and different ways of spending energy.

Finally, all results of the quantitiave phase –the statistical clusters- were integrated to the results of the subsequent phases, to create the final archetypes as shown in Table 6.1.

TABLE 6.1 Final characteristics of the archetypes

Archetype		Psychobehavioral factor	Description
Archetype 1	Restrained conventionals	Emotions	Low positive emotions, high negative emotions
		Locus of control	High external control, and low internal control
		Affordance sensitivity	Medium sensitivity
		Energy readings	Second highest saver
		Sentiments	Positive sentiments of energy, control, comfort, but neutral about affordance needs
		Experience highlights	Importance of outside view, personal space, social interaction
Archetype 2	Incautious realists	Emotions	Low positive emotions and highest negative ones
		Locus of control	High external control and lowest internal control
		Affordance sensitivity	Doesn't care about affordances
		Energy readings	Second highest waster
		Sentiments	Negative sentiments about comfort, positive about energy, affordances, and control
		Experience highlights	Importance of freedom of action, appropriate size and layout of home, but awareness of energy use
Archetype 3	Positive savers	Emotions	Second Highest positive emotions and lowest negative emotions
		Locus of control	Lowest external control, and high internal control
		Affordance sensitivity	Slight affordance indifference
		Energy readings	Highest energy saver
		Sentiments	Positive sentiments about affordances and comfort, negative about energy and control
		Experience highlights	Importance of cleanliness, feeling of control, cares about finances of energy
Archetype 4	Sensitive wasters	Emotions	Highest positive emotions, second lowest negative emotions
		Locus of control	Low external control, and highest internal control
		Affordance sensitivity	Affordances are very important
		Energy readings	Highest waster of all
		Sentiments	Negative about energy, ambivalent about affordances, and positive about control and general comfort
		Experience highlights	Need for feeling in control, furniture and décor, awareness of drawbacks of wasting energy
Archetype 5	Vulnerable pessimists	Emotions	Lowest positive emotions, high negative emotions
		Locus of control	Highest external control, low internal control
		Affordance sensitivity	Affordances are not important
		Energy readings	Third highest waster
		Sentiments	Positive about comfort and control, ambivalent of energy and affordances
		Experience highlights	Needs aesthetics of home, technology is important, perform habitual activities

TOC

Details of the potential translations into design parameters of their specific comfort needs and energy attitudes are laid out in section 6.2.3.

6.2.3 Archetypal design parameters

This section presents a few preliminary concepts as to what environmental features are needed in the homes of each of the archetypes to save energy and to maintain their comfort. These design parameters are translated from the results of all the data gathered throughout this project; they are therefore conceptual.

The Restrained Conventional needs large windows allowing a visual connection with the outside. Because they value personal space and their own time but simultaneously they need social interaction at home, they need a home whose plan allows for a transition from private to more public. However, due to their low external control, this transition shall not be modular; the floorplan needs to be that way. Although they are not particularly aware of using energy, they are still conservative in their consumption, likely because their finances concern them. To boost their energy savings, this archetype can be given real-time monetary readings of their expenditure.

The Incautious Realist emphasizes the importance of size and layout: they need order and special places for particular things; therefore, a home whose layout is modular and can convert the function of a space into another one. The occupant should be able to modulate this on their own, as they have a high need to control. They also emphasize that they need safety: in design terms, this can be translated to haptic locks in the doors and windows or modular window frostings, which also will satisfy their need for control or as an app showing which doors and windows are open. As this is the archetype with the highest financial concern and second highest wasting patterns (yet well aware of it) but with high need for control, their homes can be equipped with a 'control station' where they can see the financial savings they make when they perform different actions, such as turning lights off, heating one room only, etc.

The Positive Saver feels comfortable with cleanliness and orderliness. As a result, their homes need materials and surfaces that are easy to clean and reach, and places for orderly storage. In addition, they emphasize a need for their activities at home, from hobbies to relaxing, reading, or dining: they need a home that allows this in an orderly way and without feeling constrained. They are the highest energy savers, however, financial aspects are not important, rather, they have green attitudes and

save energy for its own sake: this is a reason why they mention to wish to have a home powered by renewable energy. Because they also need control, care about the environment, and need cleanliness, their homes can have a smart system (similar to Keyson and Herrera, 2017), reminding them of cleaning schedules, and how their energy actions influence the environment.

The Sensitive Waster shares several similarities with Archetype 3 (the positive saver). They emphasize a need for soft tactile sensations, thus soft upholstery in their living rooms, studios, and bedrooms. They need appropriate spaces in the house for their personal activities from playing instruments to inviting friends; however, they can perform this in a single multifunctional space but with the adequate affordances depending on their activities. Similar to Archetype 3, they have a high need to control their environment and green attitudes; yet, they are the biggest energy consumers of all. Because for them finances are not a priority but saving the environment is, a feedback device can be designed for them to see a balance between their energy use, their actions, and the repercussions they have on the planet.

The Vulnerable Pessimist values the aesthetics of the house, and is a technology savvy homeowner that wants gadgets in their homes. This archetype places the emphasis on the community, rather than the house itself, and hence seems to prefer interconnected compounds that allow interaction among homeowners. Finances and energy are not their concern, and are midway between savers and wasters. Although they feel they cannot control their environment, they see control as something they could have, and as result need empowering tools. One of these can be small communal living, in which they can compare consumption amongst the different occupants, which could encourage energy savings.

6.3 Limitations

The basis of the thesis was on the respondents to the questionnaire. It was administered to a sample of 761 respondents, including bachelor and master students, and staff members from Saint Gobain Recherhe and from the Applied Sciences faculty of the TU Delft.

This makes the sample population non-representative, as it is too young, it has a proportionally too high an education, and the average housing type is

not represented, and is culturally heterogeneous. Therefore, in the future it is recommended to administer the questionnaire to a wider audience in terms of demographics (education, age, background) and also in terms of sample size. Widening the target group could result in different archetypes, however, large differences should not be expected as the number of archetypes, and their characteristics are comparable to what can be found in the current literature (chapter 4).

A larger sample in the field study is especially important to be able to make statistical relationships between the occupants and their building features in the current context. Similarly, the main improvement for the interviews themselves is to have a larger sample (Mason, 2010). For the analysis type, in this work the sentiment analysis was performed. However, several other methods exist to analyse interview transcriptions, and they should be experimented with. Some examples of other analysis techniques that could be used would be affinity diagramming, other types of text mining or computational linguistic techniques, or recursive abstraction. The choice depends on the data to be extracted and whether the analysis is qualitative or quantitative (Leech & Onwuegbuzi, 2008). In this study the choice of this method was to bring objectivity to the analysis, knowing that upcoming studies (Chapter 5) would be purely qualitative.

For the IEQ monitoring, it is recommended to take the measurements for longer periods -from two weeks to a month- as is typically seen in the field, although no standard protocol exists for this. Additionally, the readings were made during the summer. The reason for doing this was to avoid the typical results with thermal comfort and heating energy consumption; and to limit the energy use variables to only what the person consumes in the summer excluding heat. However, it could be beneficial to perform the field study and the readings in different seasons, not only to include heating factors, but also to find out potential behavioural changes related to the seasons.

For the focus group, more participants are needed, as it would lead to more data that would be easier to relate to the archetypes, and more data would enable generating stronger design concepts during the ideation phase in the future. The right amount of participants can only be determined until data saturation is achieved (Guest et al. 2006; Mason, 2010).

The final limitation is with the assessment of habits. It was explained that habits are responses that are semi-automatic and highly unconscious, frequent, and contextual. The questionnaire assessed habit strengths with the Self-Report Index of Habit Strength, which gives an ideas as to what may be habits exercised by the

respondents, but it is not known whether these are real habits, as they are difficult to self-report, due to their unconscious and automatic nature. Similarly, in the interviews and the generative sessions, habits were assessed by asking questions and by requesting to fill out the diary in the sensitizing booklet. Yet, none of these ways are completely successful to capture the habits themselves. Literature suggests that for daily habits, self-report can capture habit strength, but direct assessment of the context and response, are the most valid ways to capture. This can be done by in-situ observations or video recording, which brings ethical questions for the study of habits in homes.

6.4 Future process recommendations

The research resulted in five occupant archetypes. For each one of them, there are large amounts of data that can be translated into design parameters, and eventually into concepts, and future customized products, services, or systems that will support the archetype's behaviours, save energy, while satisfying their comfort needs and expectations.

In the human-centered design process, what has been done in this work can be viewed as the first phase of the process, where empathy with the occupants is gained by learning about them, and where points of views based on their needs are constructed. The typical stages following those steps are to ideate, prototype, and test (IDEO.org, 2015, Brown, 2009).

In ideation, what has been learned from the archetypes in the questionnaire, interviews, and focus groups has to be shared with a multidisciplinary design team comprising different stakeholders (occupants, designers, contractors, architects, etc), to make sense of all the data to identify design opportunities, by brainstorming an coming up with creative solutions (IDEO.org, 2015, Brown, 2009).

Next, the best solutions should be further developed into design concepts, and eventually into prototypes. In the prototyping phase, the main components of the design concept are built, by always keeping in mind that such components need to satisfy the behavioural and comfort needs of the archetype. It is at this stage that further physical and technical characteristics are developed, as to how the idea works (IDEO.org, 2015, Brown, 2009).

In the testing stage, the built prototypes are tested with participants from the archetype that the solution is designed for. During the testing, the response of the user has to be monitored to assess if the solution responds to the initial problem found for the particular archetype. Testing can take time, especially if it is a system or service that is being assessed (IDEO.org, 2015, Brown, 2009).

Once these new products, services or systems are in the market, and an "archetype-environment" model exists, architects, engineers, or contractors can administer the questionnaire to the future occupant, so they know which archetype the future occupant belongs to, and then they can implement those products in the homes were the occupants will live.

6.5 Future research recommendations

As previously laid out, this work acts as a pathfinder for future research in the field of IEQ, and therefore this work can be used as a guiding framework for future research of comfort and energy behaviours.

The recommendations are listed below in chronological order:

1. Be presented with instant result after taking questionnaire
2. Increase number of respondents
3. Increase number of field study dwellings
4. Increase number of interviewees and focus group participants
5. Carry out ideation, prototyping, and testing phases
6. Develop an 'archetype-environment' match matrix.

For the last point, developing the archetype-environment needs the following approach. Archetypes may be dynamic over time, and as a result, longitudinal studies should be performed, thus studying the same group of people over a longer period. The objective of this is to observe not only how the archetypes change behaviourally but also in terms of their responses to other environmental stressors. Therefore, their environment has also to be monitored parallelly in the long term. Such study should, similar to the present work, be a mixed-methods triangulation, in which both qualitative and quantitiave data are gathered in a parallel fashion, to validate and confirm each other. As a result, during a long period, at different points,

environmental data has to be monitored (beyond the IEQ factors) while also taking into account what the archetypes say in interviews at different points in time.

The value of a longitudinal triangulation is that it can enable to better develop an archetype-environment system, in which archetypes are the conglomeration of qualitative and quantitative studies (behavioural, self-reported, and physiological) and the environment are also patterns of environmental stimuli (both negative and positive) varying from chemical to physical.

This archetype-environment system would therefore allow knowing what different types of persons need to thrive and be healthy and comfortable. It would also allow what they do not need and what may affect their health negatively, and how to change the environment accordingly over time, as the archetype evolves (Bluyssen, 2019).

6.6 Implications

This work shows that by stepping back from the traditional ways in which the topic is studied opens up the space for new techniques and results, and hence different views and knowledge of home occupants, their energy-consumption patterns, and comfort behaviours. By drawing inspiration from a human-centered perspective, this work shows the first phase before ideating better-performing energy-saving technologies, because in this way, we learn how to better understand home occupants, their lives, hopes, desires, which teach us how to tackle the energy challenge.

As a result, with the methodology of this work along with its individual results, it is shown that:

- Qualitative methods can be used to study comfort-making energy-consuming behaviours,
- Home occupants can be grouped into types of differing psychobehavioral characteristics.
- The methods used in this work are reliable to find archetypes.
- The archetypes generated match profiles performed in other studies (chapter 4) albeit; the ones in this work are more comprehensive.

This work is a first attempt in the IEQ field and the energy engineering field to develop archetypes in this comprehensive way. This was done by taking into account the factors used in this study and to use further qualitative data to strengthen the clusters, the work acts as a pathfinder to improve the study of comfort, energy, and technology development with an innovative technique.

Practical implications of this work are the following: for the design of buildings, for the existing stock, and for simulation and predictions. The archetypes can be used in prediction making models, in order to enter different behavioural variables, to make more accurate simulations. For architects, it can make the design process more inclusive a participatory. By knowing what archetype their clients belong to, architects may be able to make better decisions based on real needs, eliminating desirability bias. In the existing housing stock, especially for housing corporations (i.e. containers, old office buildings) knowing what the archetype of the future occupant can help to customize the spaces with specific appliances, interfaces, or feedback information that will help save energy while improving comfort. Furthermore, knowing the archetype of a future occupant can also help allocate or select different types of future occupants into the existing housing, depending on the characteristics of the current location.

As far as policy is concerned, the results of this study suggest that energy efficiency policies and programs should provide the option for stakeholders involved in supply, feedback, and interfaces of technical devices to better adapt to the archetypes' needs and requirements. Policies and programmes to reduce energy consumption in residences should also encourage the research and design of the technologies to accommodate the needs of the different archetypes, so as to give final occupants more 'flexible' technologies fitting their comfort and energy behaviours. Having the archetypes, can therefore allow for closing the gap between occupants and energy.

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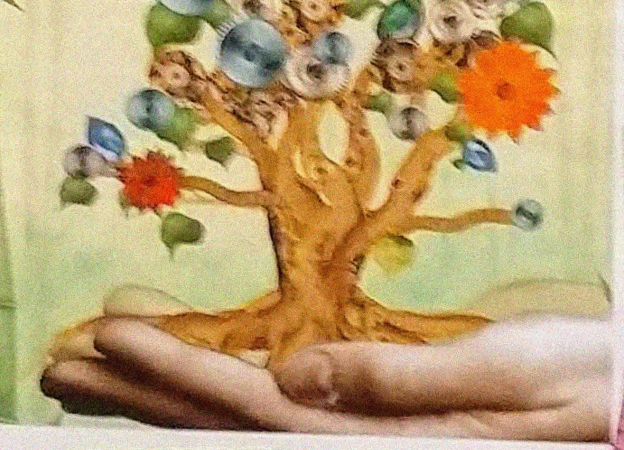
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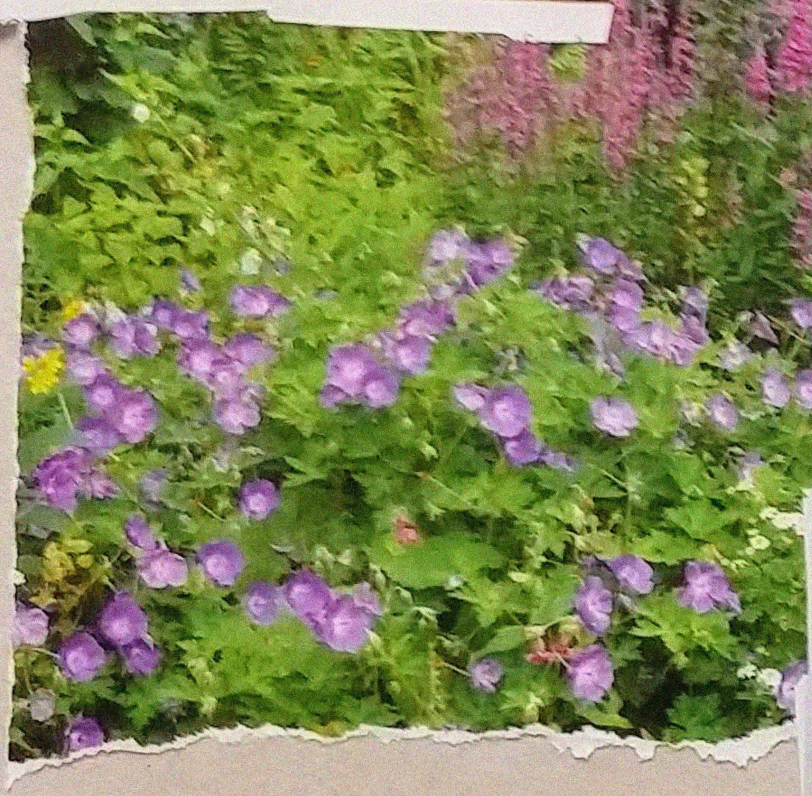
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TOC











Woudreus als paddenstoelen uit de grond. De protesten zijn dit keer niet gericht tegen hongerende grote grazers, maar keren zich tegen de kap van onze bossen. Volgens sommigen een geldverslindende bezigheidstherapie voor terreinbeheerders en ecologen, ten onrechte gebaseerd op herstel van oude cultuurlandschapen en biodiversiteit.



TOC

PART 5

Appendices







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Het sluitend krijgen van de Natura 2000-puzzels vereist een complex en deskundig systeemherstel. Op diverse plaatsen, zoals de beekdalen, heide- en

jectiel. Veel mensen houden v
afwisseling, sommigen houden van woeste oernatuur en anderen hebben weer voorkeur voor een veilig parkachtig landschap.

eens aan een heldere integrale en aansprekende natuurvisie waar ook publiek en bestuurders blij van worden.

TOC

APPENDIX A

Questionnaire

English

Default Question Block

Welcome!

Why this survey?

We take for granted that we can have a comfortable home environment, but to make it possible, energy needs to be spent, while at the same time, what we think it's a comfortable environment could have a detrimental effect on the occupants' health. The purpose of this survey is to explore the relationships between occupants' comfort and energy behaviors and their health status. The drivers of the study are the different routines and habits people perform at home to feel comfortable.

The goal is to learn more how comfort and energy savings can be optimized, while maintaining good health.

It will take about **20 minutes** to complete this survey and it is best to fill it out when you are in your home. In this survey, the term 'home' means the house where you're living during your studies.

What's in this survey?

The survey starts with basic personal and home information, which is followed by four parts: energy attitudes, health status, comfort needs, and comfort beliefs.
The purpose of the contact information is to reach you for the future parts of this research if your are willing to participate. The information and the results will remain **anonymous** and will only be used for this research.

Your contact information will not be shared or given to third parties.

Please answer all of the questions in all honesty and without overthinking. There is no right or wrong answer; it is what you do and what you think. If you do not feel comfortable answering a question, you can skip it.

If you have any questions regarding the survey or the research, feel free to contact me.

Thanks for participating!

Marco Ortiz, MSc.
Ph.D Researcher, TU Delft
M.A.OrtizSanchez@tudelft.nl





What is your age?

What is your gender?

- ○ Male
- ○ Female

What is the highest educational level that you have completed?

- ○ Primary or Secondary school
- ○ Some college
- ○ Completed Bachelors
- ○ Completed Masters
- ○ Doctorate

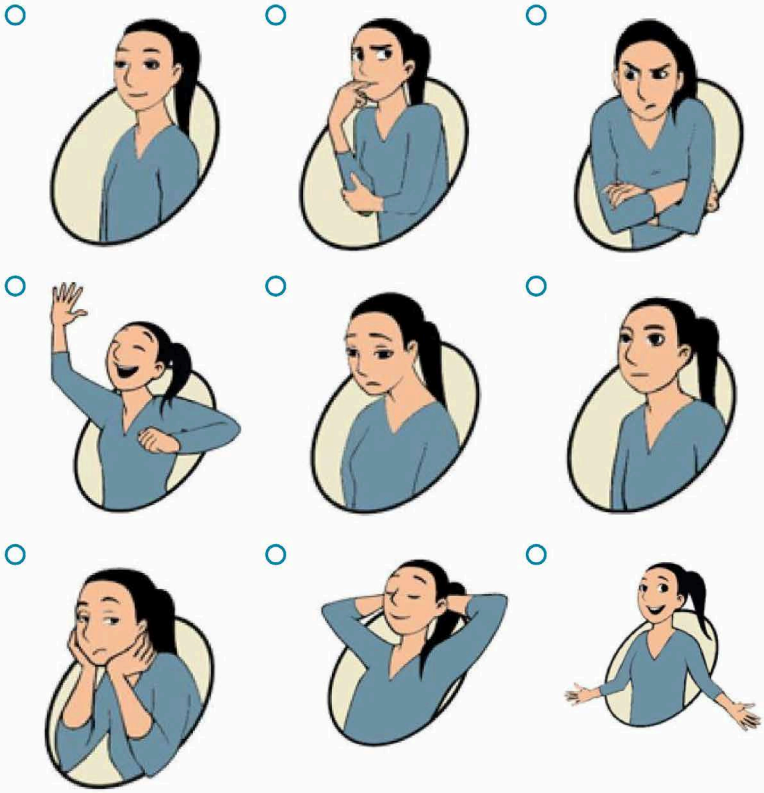
What is your nationality?

Dutch ▼

TOC

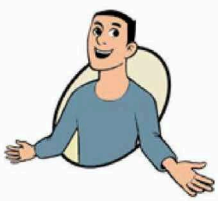
Current Mood

Which of the pictures more accurately depicts your mood right now?

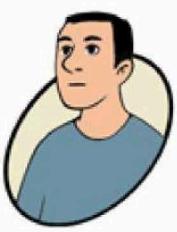


Which of the pictures more accurately depicts your mood right?

TOC





○ 
○ 
○ 

○ 
○ 
○ 

In which municipality is your home located?

Delft ▼

What type of building is it?

○ Apartment

TOC

- ○ Gallery apartment (with main door in a common external corridor)
- ○ Row house (with shared side walls)
- ○ Semidetached house (sharing one common wall)
- ○ Detached house (free-standing)
- ○ Other

Quel type de logement avez vous?

- ○ Appartement
- ○ Maison mitoyenne (avec des parois latérales partagées)
- ○ Maison jumelée (partageant un mur commun)
- ○ Maison individuelle (independante)
- ○ Autre

In what year was your building built?

- ○ Before 1945
- ○ 1946-1965
- ○ 1966-1975
- ○ 1976-1988
- ○ 1989-2000
- ○ After 2000
- ○ I don't know

How many occupants are there in your home, including you?

Over 18

Under 18

The occupants consist of:

- ○ Family members
- ○ Housemates
- ○ (Un)married couple

- ○ Only me

Are you an owner or renter?

- ○ Owner
- ○ Renter

How long have you been living in your home?

- ○ Less than 3 months
- ○ 4 to 11 months
- ○ 1 - 2 years
- ○ 3 - 4 years
- ○ More than 5 years

Would you be interested in participating in a follow-up of this research in the future?

- ○ Yes
- ○ No

Please enter your e-mail address.

Part 1: Energy Behaviors

Approximately how big is your dwelling in square meters?

How many rooms (bedrooms, living-room, kitchen) does your home have?

Please rate how you consider your behavior for each of the following statements.

TOC

	Much more	Somewhat more	About the same	Somewhat less	Much less
The amount of space heating I use compared to others is...	○	○	○	○	○
The amount of water heating I use compared to others is...	○	○	○	○	○
The amount of electric appliances I use compared to others is...	○	○	○	○	○

I make an effort to be sustainable.

- ○ Yes
- ○ No

Do you know your monthly electricity consumption in your entire household?

- ○ No
- ○ Yes

Please indicate the amount in the adequate unit.

kWh / month

Euros / month

Do you know your monthly gas consumption in your entire household?

- ○ No
- ○ Yes

Please indicate the amount in the adequate unit.

cubic meters / month

Euros / month

Please indicate your agreement with the following statement:
I perform the activities I need, regardless of the energy I need to spend.

- ○ Yes
- ○ No

Please rate your willingness with each of the following statements:

	Definitely yes	Probably yes	Might or might not	Probably not	Definitely not
I am willing to change my daily behavior to be more sustainable	○	○	○	○	○
I am willing to give up comfort for the sake of saving energy	○	○	○	○	○

---

habits

Please think of your past actions at home and choose if you GENERALLY have to spend energy or not for the specific behavior.

	I generally have to spend energy to do this **by all means**.	I generally do this **without** spending any energy.
I want to relax or feel stress-free.	○	○
I want to make myself warm.	○	○
I want order, cleanliness, or tidiness.	○	○
I personalize the place, make it feel 'mine'.	○	○
I socialize in person.	○	○
I want to eat	○	○
I socialize online.	○	○
I want to feel refreshed or cool.	○	○
I try to feel safe or secure.	○	○
I'm doing my hobbies.	○	○
I create the right atmosphere or mood.	○	○
Others:	○	○

TOC

block 3 health

Part 2: Health Status

Have you suffered from any of these diseases or problems in the last 12 months?

	Never	Yes, in the last 12 months	Yes, but not in the last 12 months
Asthma	O	O	O
Bronchitis / bronchial pneumonia	O	O	O
Wheezing or whistling in the chest	O	O	O
Other chest conditions	O	O	O
Hay fever	O	O	O
Allergic rhinitis (runny/itchy nose, watery/itchy eyes, frequent sneezing/coughing)	O	O	O

	Never	Yes, in the last 12 months	Yes, but not in the last 12 months
Eczema	O	O	O
Dermatitis	O	O	O
Other skin conditions	O	O	O
High lipids in the blood (i.e. cholesterol, triglycerides)	O	O	O
Diabetes	O	O	O
High blood pressure	O	O	O

	Never	Yes, in the last 12 months	Yes, but not in the last 12 months
Other heart conditions	O	O	O
Migraine	O	O	O
Depression	O	O	O
Anxiety	O	O	O
Psychiatric problems	O	O	O
Other diseases / problems	O	O	O

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Dry eyes	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Itchy or watery eyes	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Blocked or stuffy nose	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Runny nose	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Sneezing	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Dry throat	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Lethargy or tiredness	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Headaches	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure

- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Dry, itchy, or irritated skin	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Any kind of breathing difficulty	○	○	○	○	○

Is it related to your home indoor environment?

- ○ Yes
- ○ Partly
- ○ Not sure
- ○ No

In the last 3 months, on average how often have you suffered from the following symptoms **while being at home**?

	Every day	3-4 days a week	1-2 days a week	Once every 2-3 weeks	Less often or never
Any other symptoms	○	○	○	○	○

Is it related to your home indoor environment?

- Yes
- Partly
- Not sure
- No

Block comfort

Part 3: Comfort Control Beliefs

Read carefully each of the following statements and select a number from 1 to 5, according to how you feel about them.

	Strongly Disagree 1	2	3	4	5	Strongly Agree 6
I am able to do the activities I want in my home, in accordance to my personal ideas.	○	○	○	○	○	○
Having a stress-free environment in my home is all luck: I cannot influence it.	○	○	○	○	○	○
The feeling of privacy in my home is entirely determined by myself.	○	○	○	○	○	○
The character or 'mood' of my home is something that just happens by itself.	○	○	○	○	○	○
Regardless of the size and areas of my home, I feel comfortable there.	○	○	○	○	○	○
It is up to me whether my home is kept in a tidy and clean state.	○	○	○	○	○	○

	Strongly Disagree 1	2	3	4	5	Strongly Agree 6
To a great extent, I do not plan the actions and activities that I carry out in my home.	○	○	○	○	○	○
Whether or not my home offers me the feeling of privacy depends on fortunate circumstances.	○	○	○	○	○	○
I carefully control the temperature of my home.	○	○	○	○	○	○

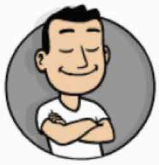
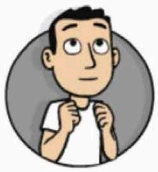
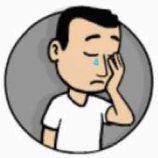
	Strongly Disagree 1	2	3	4	5	Strongly Agree 6
I make sure I have a presentable home, based on its features (i.e. types of materials, furniture, products, etc)	O	O	O	O	O	O
Being comfortable in my home is a matter of the layout and size of my house.	O	O	O	O	O	O
It is only a coincidence whether my home seems to reflect my personality or not.	O	O	O	O	O	O

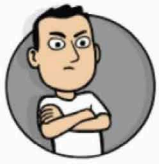
	Strongly Disagree 1	2	3	4	5	Strongly Agree 6
I am able to relax at home whenever I want.	O	O	O	O	O	O
I can't completely control the cleanliness and tidiness of my home: they are the result of time.	O	O	O	O	O	O
The way my home looks and feels depends on my own personal taste.	O	O	O	O	O	O
The temperature in my home is pretty much determined by the house itself.	O	O	O	O	O	O
It do not mind what type of features (i.e. types of materials, furniture, products, etc) are in my home.	O	O	O	O	O	O
I make an effort to get the right atmosphere and mood of my home.	O	O	O	O	O	O

Please think of your home environment and indicate the emotions you feel about it, and their intensity.

Rate the level of the emotions based on the scale, 1= I do not feel this; 2= I feel this a little; 3= I feel this somewhat; 4= I do feel this; 5= I do feel this strongly.

I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5

	I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5
Desire 	O	O	O	O	O
Satisfaction 	O	O	O	O	O
Disgust 	O	O	O	O	O
Hope 	O	O	O	O	O
Sadness 	O	O	O	O	O

	I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5
	I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5
Joy 	○	○	○	○	○
Interest 	○	○	○	○	○
Dissatisfaction 	○	○	○	○	○
Admiration 	○	○	○	○	○

TOC

	I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5
Shame 	○	○	○	○	○

	I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5
Fear 	○	○	○	○	○
Pride 	○	○	○	○	○
Boredom 	○	○	○	○	○

	I do not feel this 1	I feel this a little 2	I feel this somewhat 3	I do feel this 4	I do feel this strongly 5
Contempt 	O	O	O	O	O

Part 4: Comfort Hierarchy

When you feel or make yourself comfortable in your home, what are the aspects of your home that enable this?

Please rate the aspects from 1 = Not important to 5 = Very important.

	Not important 1	2	3	4	Very important 5
An adequate temperature for what I do					
Dust-free, odorless, fresh air					
An appropriate acoustical environment, without noise from building systems, appliances, streets, or neighbors.					
The right amount of natural and/or artificial lighting for the activities I do at home					

	Not important 1	2	3	4	Very important 5
The freedom and possibility of doing the activities I want in my home					
A feeling of control over the place, the systems, etc.					
The sense of freedom of being and expressing myself.					
The sense of security and/or privacy					
The adequate spaces or right size for the activities I need or want to do.					
The sense of cleanliness and orderliness					

Thank you for completing the questionnaire!

Click "Next" to finish, or feel free to express what 'comfort' means to you.
Or, if any, please write your comments, remarks, or suggestions about this survey.

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TOC

APPENDIX B

Tables pertaining to Chapter 2

TABLE APP.B.1 Scope of comfort by discipline and by human and environmental factors.

		IEQ	Nursing/ Healthcare	Ergonomics	Popular	Evolutionary	Domestic	Holistic
Environmental factors	Air quality	+				+ Olfaction/ irritation		
	Temperature	+	+			+		
	Visual	+	+			+		
	Acoustical	+	+			+		
	Size/layout						+	
	Interior design (colour, greenery,....)		+ 'Positive stimuli'		+ General environment	+ Environmental stimuli	+	+ General environment
	Other affordances			+		Contextual cues	+	
Human factors	Physiological	+	+		+	+	+	+
	Psychological		+ Psycho-spiritual		+	+	+ Privacy/ security	+
	Social		+ Support			+	+ Interaction	
	Physical		+	+		+		+
	Emotional		+		+	+	+ Identification/ Attachment/ Expression	
	Behavioural	+ Adaptive	+	+		+	+	
	Postural		+	+				

Legend:
+ means that the factor is included in that discipline
[empty cell] means that the factor is disregarded in the discipline
Written content: sub-element of the environmental or human factor studied in the discipline.

TOC

TABLE APP.B.2 Effects of energy efficient measures on health of occupants.

Reference	Evidence level	Country and date	Variables or indicators		Building type	Population	Effect on health of variables / indicators – Main results
			Indicator	Health			
(Thomson et al., 2009)	1 (systematic review of experimental studies)	Varied , from 1887 to 2007	Warmth measures	Respiratory, general, mental	Varied	Varied	Positive
(Thomson et al., 2013)	1 (systematic review of experimental studies)	Varied , from 1887 to 2012	Housing investments /interventions (warmth measures)	General health (respiratory, absenteeism), illness, wellbeing	All physical house types	All types of participants	Positive
(Rashid & Zimring, 2008)	3 (systematic review of correlational or qualitative studies)	Varied	Light, temperature, air, acoustical	Stress	Laboratory, offices, residences	Varied	Negative
(Maidment et al., 2014)	1 (meta-analysis of experimental studies)	Varied	Insulation, heating, glazing,	General health; respiratory	Varied	36 studies / 33000 participants	Positive marginal effects. Improve over time
(Mendell, Mirer, Cheung, & Douwes, 2011)	1 (review of epidemiologic evidence)	Varied	dampness or mould	multiple allergic and respiratory effects	Varied	Varied	negative
(Howden-Chapman et al., 2007)	2 (Community based, cluster, single blinded randomized study)	New Zealand	Insulation (temperature, humidity, energy consumption)	Self-reported, wheezing, days off, GP visits, hospitalization	1350 low-income households, uninsulated dwellings.	4407 participants of households with previous respiratory history.	Positive (reduced odds of poor effects)
(Liddell & Morris, 2010)	6 (narrative synthesis)	England, Wales, Scotland, New Zealand, USA (2000-2009)	Fuel poverty (cold and damp housing)	Mental, physical health	Households	5 studies with more than 2000 households each. Infants and adults	Modest effects in adults, more significant in infants.
(Wilson et al., 2014)	6 (single descriptive qualitative study)	Boston, Chicago, new York city (2009-2012)	insulation, heating equipment, ventilation improvements	self-reported general, respiratory, cardiovascular, and mental health	248 Households	248 adults, 75 children	Positive effect on sinusitis, general health, and asthma medication.
(Fisk, Lei-Gomez, & Mendell, 2007)	1 (quantitative meta-analyses	Varied	dampness and mould	respiratory and asthma-related health outcomes	Homes	male adults, female adults, children (Age < 18), and infants.	Negative (30%–50% increases in respiratory and asthma related health outcomes)
(Leech et al., 2004)	4 (case-control study with telephone-administered questionnaire)	New Brunswick and Nova Scotia, Canada (1998)	New homes with heat recovery ventilators	Respiratory symptoms, diagnosed asthma, chronic obstructive lung disease, heart condition, medication use.	53 new homes	149 occupants	Positive effects over 1 year.
(Butz et al., 2011)	2-3 (Randomized controlled trial, with randomization embedded in study database)	Baltimore, USA	PMs, air nicotine, urine cotinine concentrations	Symptom free days	Johns Hopkins Hospital Children's Centre and homes of children	Children with asthma, residing with a smoker, randomly assigned to interventions consisting of air cleaners only (n = 41), air cleaners plus a health coach (n = 41), or delayed air cleaner (control) (n = 44).	Air cleaners reduce PM concentrations and increase symptom-free days. SHS exposure not prevented
(Norbäck, Lampa, & Engvall, 2014)	6 (self-administered postal questionnaire)	Sweden	Multiple building characteristics	Asthma, allergy and eczema, hay fever.	472 multifamily buildings	7,554 participants	Asthma, allergies or eczema more common with less use of energy for space heating, in larger buildings and in dwellings with redecoration, mould odour, dampness and humid air.

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TOC

TABLE APP.B.2 Effects of energy efficient measures on health of occupants.

Reference	Evidence level	Country and date	Variables or indicators		Building type	Population	Effect on health of variables / indicators – Main results
			Indicator	Health			
(Sun & Sundell, 2013)	6 (descriptive –cross-sectional study)	Northeast Texas (2008-2009)	housing characteristics, home interior surface materials, dampness	wheeze, dry cough, rhinitis, eczema	Trailers and apartments.	2,819 parents of children	Living in trailers was related to diagnosed asthma and diagnosed hay fever. Central A/C systems associated with an increment of allergic symptoms, especially rhinitis.
(Bornehag et al., 2005)	3 (cross-sectional, correlational)	Sweden	Water leakage, visible dampness, floor moisture, window condensation	Wheeze, cough, eczema, rhinitis, asthma	8918 homes.	10,851 children (1-6 years)	Dampness indices were associated to higher prevalence of symptoms
(Barton et al., 2007)	2 (randomized to waiting list)	Devon UK	Upgrading houses (including central heating, ventilation, rewiring, insulation, and re-roofing)	General health Respiratory health. Musculoskeletal health. Health service contacts. Hospital admissions.	119 council owned houses	480 residents of these houses.	lessening of asthma symptoms in adults and appears to protect against non-asthma respiratory conditions in adults and children
(Sharpe et al., 2015)	6 (Postal questionnaire)	United Kingdom	household energy efficiency	Asthma outcomes	3867 social housing properties	944 participants	Increased energy efficiency may increase risk of current asthma. Mouldy/musty odour associated with risk of asthma
(Fisk, 2013)	1 (systematic review)	varied	particle filtration	Self-reported health and measured allergy, asthma, inflammation, respiratory system performance, lung function, blood pressure, heart rate.	Non-industrial buildings (homes, schools, and offices)	Varied	Particle filtration modest effect in reduction allergy and asthma outcomes. Not very effective in reducing acute health symptoms in non-allergics/ asthmatics. Morbidity and mortality associated with particle exposure is reduced.
(Lanphear et al., 2011)	2 (double-blind, randomized trial)	area surrounding Cincinnati, USA	Air nicotine levels, tobacco smoke exposure, indoor airborne particle levels, and exhaled nitric-oxide levels	unscheduled asthma visits and symptoms	Homes of participants.	225 children (6-12 y.o.) with asthma, exposed to SHS	HEPA air cleaners may reduce asthma morbidity
(Thomson et al., 2001)	1 (Systematic review of experimental and non-experimental)	Varied	interventions to improve housing (rehousing, refurbishment, and energy efficiency measures)	health effects	Varied	Varied	Most studies found some health gains, but inconclusive evidence due to small samples.
(Willand et al., 2015)	1 (systematic review of intervention studies)	Varied	energy efficiency interventions (warmth, affordability of fuel, psycho-social factors, indoor air quality)	Physiological, social, psychological health.	Residences	Varied	EEI improved winter warmth and lowered relative humidity with benefits for cardiovascular and respiratory health.
(Bone, Murray, Myers, Dengel, & Crump, 2010)	6 (narrative synthesis)	UK	energy-efficient measures	General health	UK homes	Varied	Poor ventilation, overheating, poor IAQ may affect health.

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TABLE APP.B.2 Effects of energy efficient measures on health of occupants.

Reference	Evidence level	Country and date	Variables or indicators		Building type	Population	Effect on health of variables / indicators – Main results
			Indicator	Health			
(Johnson, Mavrogianni, Ucci, Vidal-Puig, & Wardle, 2011)	1 (systematic review)	USA and UK	thermal exposures	obesity prevalence	domestic setting	Adults	Plausible causal link between increased time spent in thermal comfort and increased adiposity in the population
(Fisk, 2015)	3 (systematic review of correlational; qualitative studies, RCT or quasi-experimental studies)	Varied	Climate change; indoor exposures; changes in the building.	General health	Varied	Varied	Health effects of climate change will result from indoor exposures. Climate-related health effects can be reduced by changes to buildings. Changes to buildings will improve health irrespective of climate change. Changes to buildings will save energy and reduce CO2 emissions.
(Oreszczyn, Hong, Ridley, Wilkinson, & Group, 2006)	3 (descriptive correlational study)	England (2001-2003)	Warm front energy efficient measures (insulation and insulation)	Temperatures in household.	Dwellings with Warm Front measures	Varied	Temperatures influenced by property characteristics (age, thermal efficiency, number of people, age of the head of household). Warm front measures improve living- and bedroom temperatures
(Fisk, 2000)	3 (systematic review of correlational; qualitative studies, RCT or quasi-experimental studies)	Varied	Indoor environmental factors	Health outcomes (communicable respiratory illnesses; allergy and asthma symptoms; sick building syndrome symptoms)	Varied	Varied	Characteristics of buildings and indoor environments influence SBS, respiratory, and allergy and asthma symptoms. Marginally adequate indoor environment provision can be replaced by health promoting IE
(Roulet, Bluyssen, Cox, & Foradini, 2006)	3 (Descriptive correlational study)	Nine European countries	building energy performance; building characteristics and IE	Feeling and perception of IE; SBS	Apartment and office buildings	Dwellers and office workers	Low Energy buildings with good IE exist.
(Philomena M. Bluyssen, 2000)	3 (Descriptive correlational study)	Nine European countries	building energy performance; building characteristics and IE	Feeling and perception of IE; SBS	Apartment and office buildings	Dwellers and office workers	Low Energy buildings with good IE exist.
(P. Bluyssen et al., 1995b)	3 (Descriptive correlational study)	European countries	perceived indoor air quality.; pollution sources; ventilation rates and performance; energy consumption	symptoms/complaints	office buildings	Office workers	Occupants acceptability and BRS shows no correlation with perceived IAQ

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TOC

TABLE APP.B.2 Effects of energy efficient measures on health of occupants.

Reference	Evidence level	Country and date	Variables or indicators		Building type	Population	Effect on health of variables / indicators – Main results
			Indicator	Health			
(van der Lans et al., 2013)	3 (Descriptive correlational study)	Netherlands	Cold acclimatization	BAT production, NST thermogenesis.	Laboratory	17 healthy men and women	Repeated intermittent cold exposures recruited brown adipose tissue; accompanied by an increase in non-shivering thermogenesis
(van Marken Lichtenbelt et al., 2009)	3 (Descriptive correlational study)	Netherlands	Thermoneutral conditions (22C) and mild cold exposure (16 C)	Body composition and energy expenditure; Brown-adipose-tissue activity	Laboratory	24 healthy men (10 normal weight-14 overweight or obese)	BAT activity is reduced yet present in most overweight or obese men, thus may be a target for the treatment of obesity
(Nagasawa et al., 2015)	6 (longitudinal questionnaire – single descriptive qualitative study)	Japan	-	Chronic back pain; Satisfaction with living environment; Stress and fatigue	-	Japanese women 3054	Causal effect: *"stress and fatigue" -> "chronic back pain"*. Second causal effect: *"satisfaction of living environment" -> "stress and fatigue."* Thus, suggestion that "satisfaction of living environment" influences "stress and fatigue" which is manifested as "chronic low back pain".
(Wilkinson, Smith, Beevers, Tonne, & Oreszczyn, 2007)	5 (systematic reviews of descriptive and qualitative studies.)	Varied	indoor air pollution; energy-efficient homes	General health	Varied	Varied	Evidence of effects of indoor air pollution and health links is strong and partly quantified. Effects of energy-efficient homes on health, evidence is meagre.
(Sandel & Wright, 2006)	(5 (systematic reviews of descriptive and qualitative studies.)	Varied	housing quality, housing characteristics	asthma expression; psychological stress	Varied	Children	Increasing evidence has linked psychological stress and negative affective states to asthma expression

The evidence levels of the following table are determined by:
[1] G. Guyatt, D. Rennie, M. Meade, D. Cook, *Users' guides to the medical literature*, in, Chicago: AMA Press, 2002.
[2] R.P. Harris, M. Helfand, S.H. Woolf, K.N. Lohr, C.D. Mulrow, S.M. Teutsch, D. Atkins, M.W.G.T.U. Preventive, S.T. Force, Current methods of the US Preventive Services Task Force: a review of the process, *American journal of preventive medicine*, 20 (3) (2001) 21-35.
[3] J.F. Stichler, Weighing the evidence, *HERD: Health Environments Research & Design Journal*, 3 (4) (2010) 3-7.

TOC

APPENDIX C

Field Study

Interview outline

The following outline worked as a guide and was not meant to be followed step by step as the interviews were semi-structured and were conducted in the form of a dialogue.

Introduction:

Thank you for inviting us to your house, and for your time.

Do you mind if I record our conversation? This is to have transcribed later and to code it- which means that we will highlight key terms and make quantitative data out of the interview. As specified by the committee of ethics of TU, the recording will be destroyed in 6 months, and everything will be unidentifiable and anonymous.

Definition of terms:

- Energy behaviors: anything you do within your house, that has an impact on the energy bill; thus which uses either energy or gas, either directly or indirectly. i.e. Showering, cooking, opening a window in the winter, watching TV, etc.
- Comfort behaviors: any activity you perform in order to bring yourself to a state of feeling good, without psychological or physical tensions.
- The word “things” is used in this interview a few times. “Things” means products, materiality, immaterial (i.e. communication with housemates or landlord)

Part 0: Personal information

- How old are you?
- Where are you from?
- What do you do in life?
- How long have you been living in this house?
- What is your living situation (i.e. do you live alone/couple/housemates)
  - Are you used to living in this situation?
  - Do you feel at ease living the way you are?
  - What would improve it?
  - How long have you lived like this?
- How do you consider your general wellbeing?
  - Good or bad?
- Do you consider a person who is easily satisfied?
- Do you want you “own” circumstances, or you adapt easily to other circumstances?
  - i.e. Are you easy to please?
  - Or do you always want more?

Part 1: meaning of comfort

- What does comfort mean to you in your home?
- Is there a thing(s) in your home that hold sentimental value that embodies a memory, relationship, or identity?
- What are activities you enjoy doing at home? What do you look forward to, before arriving home from a long day?
  - Or activities you do to relax or destress?
- What other activities do you find “necessary” to do in your house?
  - i.e. Cleaning? Cooking? Etc.?

- How much do you feel you have control over areas and things of your house?

- What are major constraints in your home that hinder you from feeling comfort?

- HAND OUT From the following items, which of these are part of comfort for you?
  - Relaxingo
  - Socializingo
  - Sense of control (being able to control/influence the place)
    - personalizing / changing moodo
  - freedom
    - of doing what you want
    - being yourself
  - Good smells
  - Right lights
  - Right temperature
  - Quietness
  - Security
  - Hobbies
  - Coziness:
    - Tactile sensations
    - Inner warmth

- In your house, what areas or things allow you to get *chosen items*?

- Why do you use that area of thing to achieve *chosen items*?

- How/By which means does the particular area or thing allow you to achieve *chosen item*?

- From the comfort making activities you just mentioned, which ones use energy?
  - Directly or indirectly?
  - What is the frequency of the activity?

- Would you give up comfort in order to save energy?

- [If an object/appliance is involved] What is your attitude towards the appliance you use?
  - Is it frustrating, satisfying to use etc.?

- From what you mentioned that frustrates you or don't like in your home, how and why would you change it?

Part 2: Energy use

- Do you care about technology, etc?
- What are your occupancy patterns (i.e. schedules)
  - When are you actually using energy?
- - Do you know if your house has energy efficient solutions already installed?
  - Such as smart meter, double glazing, insulation, etc
- Would you install energy efficient solutions in the house, if you could?
- What would be your motivation?
  - i.e. Saving the planet, saving money, saving energy?
- How do you handle energy consumption?
- Do you consider yourself energy conscious?

Part 3: Checklist and walkthrough

- Let's have a walkthrough around your house
- .We will fill out the checklist and place the sensors in your preferred areas.
- . We will check your energy and gas meters and come back next month.
- If you don't have energy meter send us your bills.
- If no bills, we will check the appliances you use and take pictures of their wattage.

Building Checklist

Address of the home	
Street	
Number	
City	
Zip Code	
Interviewee	
Home ID	
Interviewee ID	
Aerial Picture or Orientation with surroundings	

Type of home	
End terrace	
Mid terrace	
Bungalow	
Semidetached bungalow	
Bottom floor flat or maisonette	
Semidetached house	
Detached house	
Top floor flat	
Mid floor flat or maisonette	

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Construction year	
before 1900	
1900-1929	
1930-1949	
1950-1966	
1967-1975	
1976-1982	
1983-1990	
1991-1995	
1996-2002	
2003-2006	
2007 onwards	
Number of bedrooms	
2 or fewer	
3 bedrooms	
4 bedrooms	
5 or more	
Energy Label	

Heating system				
I don't know				
Gas boiler	Natural	Installation year	Before 2005	
			After 2005	
	Butane/ propane	Installation year	Before 2005	
			After 2005	
Oil boiler		Installation year	Before 2005	
			After 2005	
LPG boiler		Installation year	Before 2005	
			After 2005	
Storage heater				
Coal boiler				
Wood boiler				
Biomass boiler				
Other system (specify):				

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Heating terminal units				
Hot water radiators or convectors				
Electrical radiators or convectors				
Heating floor				
Warm air flow				
Fireplaces	Open			
	Closed			
Other (specify):				
Radiators below windows				
Yes				
No				
Main roof type				
I don't know				
Pitched	Amount of roof insulation	None		
		1.2 cm		
		2.5 cm		
		5 cm		
		7.5 cm		
		10 cm		
		15 cm		
		20 cm		
		25 cm		
		More than 30 cm		
Loft with unknown insulation				
Loft layer of insulation	Thickness	Less tan 5 cm		
		5 to 15 cm		
		More than 15		
Flat roof	Insulation	As built		
		Insulated		
Thatched	Insulation	As built		
		Insulated		
Below heated space	Insulation	As built		
		Insulated		
Home built with rooms in the roof place		Loft conversion	Before 1991	
			After 1991	
Access to loft space?		Yes		
		No		
Presence of a room or rooms in the roof		Yes		
		No		

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Main wall type			
I don't know			
Solid brick wall with no cavity			
Solid stone wall			
Brick cavity wall	Insulated		
	Non insulated		
	Don't know		
Timber frame wall			
Concrete construction wall			
General temperature during the winter			
18 or less degrees (specify):			
19			
20			
21			
More than 22 (specify):			
Typical heating season schedules			
Working day	Outside working hours		
	Outside working hours and overnight		
	All day	Time span (specify):	
	All night	Time span (specify):	
	All day and all night		
	Other schedules (specify):		
Weekend	Outside working hours		
	Outside working hours and overnight		
	All day	Time span (specify):	
	All night	Time span (specify):	
	All day and all night		
	Other schedules (specify):		
Presence of a room or rooms in the roof			
No, none			
1			
2			
3 or more			
Number of showers taken in a typical week			
How many doors to the outside are there?			
Predominant door type			
Wood single glazing			
Wood double glazing			
Wood no glazing			
uPVC door			
Door leading to an unheated hallway			

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Predominant glazing type			
Single glazing			
Double glazing			
Double clear glazing with filling (Argon or other)			
Double clear glazing with coating			
Double glazing with tinted internal pane			
Triple glazing			
Other (specify):			
Window type			
Openable windows			
Other natural ventilation (e.g. passive stack)			
Hybrid/mixed model (natural + mechanical)			
Percentage of window opening			
All windows			
None			
Some:			%
Total window area in m^2			
Number of windows usually open		Heating season	
		Cooling season	
When are the windows open?	Cooling season	All day	
		All night	
		Morning	
		Afternoon	
		Evening	
		All day and night	
	Heating season	All day	
		All night	
		Morning	
		Afternoon	
		Evening	
		All day and night	
Presence of ventilation grids		Yes	
		No	
Opening of grids		Always	
		Often	
		Sometimes	
		Never	

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Solar sharing device		None	
		South side only	
		Other façades	
		External	
		Internal	
Shading control		No control (fixed)	
		Individual	
		Central down, individual up	
		Automatic	
		Other (specify):	
Material of grids		Wood	
		Metal	
		PVC	
Roof facing between south-east and south-west?		Yes	
		No	
Photovoltaics present		Yes	
		No	
Micro wind turbine present		Yes	
		No	
Solar hot water present		Yes	
		No	
Wood pellet store present		Yes	
		No	
Lighting	Number of rooms with only low energy bulbs	1	
		2	
		3	
		4	
		5 or more	
Appliances	During a regular summer month, how much of your washing do you dry in a tumble dryer?	None (I don't have a drier)	
		A little 10%	
		Some 25%	
		Half 50%	
		Most 75%	
		All 100%	
Number of freezers/ fridges	Fridge with freezer		
	Only freezer		
	Fridge without freezer		

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Type of cooking appliance	Only electric stove and oven		
	Coal or wood fired oven		
	Gas stove and oven		
	Gas stove with electric oven		
	Aga cooker (electric that is always hot)		
	Aga cooker (coal or gas that is always hot)		
General ventilation strategy	Natural		
	Natural assisted (exhaust)		
	Mechanical		
Type of mechanical ventilation	Supply system only		
	Both exhaust and supply		
	Exhaust system only	Location exhaust system	
		Toilets/other polluted rooms only	
		Other rooms	
		Permanent	
		Non-permanent	
		Hours per day working	
Air handling units (AHU)	100% fresh air		
	Recirculation percentage of fresh air		
	With free cooling system		
	Other (specify):		
Type of AHU control	Manual (on/off) – central		
	Manual (on/off) – local		
	Automatic	CO2 controlled	
		Other (specify):	

APPENDIX D

Tables pertaining to Chapter 4

TABLE APP.D.1 Text mining results

*	Concept (38)	Sentiment	Concept (30)	Sentiment	Concept (9)	Sentiment	Concept (11)	Sentiment	Concept (44)	Sentiment
Energy awareness and usage	– Bill 7 – Paid 3 – lifestyle 2 – comfort 2 – shower 2	– energy + <PositiveAttitude> – lifestyle + <Positive> – comfort + <Negative> – shower + <Negative> – bill + <PositiveCompetence>	– Consumption 4 – People 2 – Lights 3 – Technology 2 – Shower length 2	– consumption + <Positive> – people + <Positive> – technology + <Positive> – shower length + <PositiveAttitude>	– waste 2 – double 1 – energy 1 – money 1 – light 1 – heating 1	– heating + <NegativeFunctioning> – light + <PositiveFeeling> – double + <Negative> – energy + <Negative>	– environment 1 – energy 1 – lights 1 – finances 1 – change 1	– energy + <Negative> – environment + <Positive> – finance + <Negative>	– Bill 9 – Neighbours 4 – Technology 4 – Devices 3 – Energy 2	– bill + <PositiveCompetence> – energy + <Negative> – neighbors + <Negative> – technology + <Positive> – devices + <Positive> – house + <NegativeFeeling>
General comfort and future home	– (54) – Garden 6 – City 4 – View 4 – Privacy 4 – Mind 2	– garden + <PositiveFeeling> – mind + <PositiveFeeling> – air + <PositiveFeeling> – kitchen + <Positive> – privacy + <Positive> – sunlight + <Positive> – view + <Positive>	– (52) – Air 6 – Sunshine 5 – Peaceful 4 – Pleasant 2 – Productive2 –	– air + <Negative> – sunshine + <PositiveFeeling> – pleasant + <Positive>	– (61) – Atmosphere 8 – Lamps 5 – Freedom 5 – Historic 3 – Heating 2	– "air + <PositiveFeeling> – atmosphere + <PositiveFeeling> – ceiling lamps + <Negative> – freedom + <Negative> – chairs + <Positive> – heating + <PositiveFeeling> – place + <PositiveFeeling> – house + <Positive>	– (42) – Room 6 – Temperature 4 – Lights 3 – Ventilation 3 – Windows 3	– temperature + <Positive> – lights + <Positive> – ventilation + <Positive> – windows + <PositiveFeeling – rooms + <Positive>	– (57) – Eating 7 – Softness 4 – Work 4 – Belonging 2 – House 2	– lighting + <Positive> – softness + <Positive> – temperature + <Positive> – work + <PositiveFeeling> – bathroom + <Positive> – belongings + <Positive> – house + <Positive>
Sense of control	– (29) – Avoid 2 – Color 2 – Fresh 1 – Open 1 – Cooking 1	– "air + <PositiveFeeling> – control + <Positive> – cooking + <Positive> – hotel + <NegativeFeeling> – "	– (23) – Ownership 2 – Own 2 – Possessions 1 – Attractive 1 – Studio 1	– ownership + <NegativeCompetence> – possessions + <Positive> – studio + <Positive>	– (19) – People 2 – Decoration 1 – Objects 1 – Heating 1 – Grids 1	– grids + <Negative> – objects + <Negative> – people + <Negative>	– (15) – Change 1 – Plants 1 – Picture 1 – Control 1 – Decorating 1	– "control + <PositiveFeeling> – home + <Positive> – decorating + <Positive> – "	– (18) – Comfort 3 – Rugs 2 – Sofa 2 – Stuffiness 2 – Temperature 1	– "comfort + <PositiveAttitude> – rugs + <Positive> – feel + <PositiveFeeling> – stuffiness + <NegativeFeeling> – "
freedom	– (14) – doors 2 – closed 1 – not free 1 – mother 1 – hallway	– doors + <Negative>	– (16) – complaint 3 – loud 1 – music 1 – play 1 – neighbors 1	– neighbors + <Positive>	– (5) – hobbies 1 – freedom 1 – people 1 – room 1 – relaxing 1	– hobbies + <PositiveFeeling>	– (8) – freely 1 – music 1 – noises 1 – dancing 1 – sacrifices 1	– sacrifices + <Negative>	– (15) – loud 2 – people 1 – music 1 – communal space 1 – play 1	– clothes + <PositiveFeeling> people + <Positive>

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TOC

TABLE APP.D.1 Text mining results

*	Concept (38)	Sentiment	Concept (30)	Sentiment	Concept (9)	Sentiment	Concept (11)	Sentiment	Concept (44)	Sentiment
Temperature	– (15) – cold 3 – temperature 3 – good 2 – hot 1 – relaxing 1	– temperature + <Positive> cold + <PositiveFeeling>	– (9) – fast 1 – cold 1 – ventilation 1 – air 1 – zone 1	– air + <Positive> temperature + <PositiveFeeling> cold + <Positive>	– (2) – warm 1 – temperature 1	– temperature + <PositiveFeeling>	– (42) – open 2 – cold 2 – windows 2 – temperature 2 – closed 1 – layer 1	– layer + <Negative> thermostat automation + <Negative> temperature + <Positive>	– (22) – open 2 – window 2 – room 2 – winter 2 – warm 1	– central system + <Negative> winter + <Negative> warm + <NegativeAttitude>
Smells	– (15) – normal 4 – bad 1 – disgusting 1 – dislike 1 – room 1	– smell + <NegativeCompetence>	– (3) – comfort 1 – not relevant 1 – smell 1	– smell + <PositiveFeeling>	– (3) – like 1 – comfortable 1 – smell 1	– smells + <Positive>	– (4) – irritating 2 – people 1 – smoke 1 – smell 1	– smell + <Negative> smell + <Positive>	– (12) – bad 3 – hygiene 1 – feel 1 – toilet 1 – sink 1	– sink + <NegativeCompetence>
Light	– (38) – dim 3 – like 2 – brightness 2 – atmosphere 2 – eyes 1	– activities + <Positive> lights + <Positive> sunlight + <Positive> comfort + <NegativeCompetence> eyes + <Negative>	– na	– na	– (22) – old 2 – right 2 – warmer 1 – lighting 1 – contrast 1	– color + <NegativeAttitude> contrast + <Negative> lighting + <Positive> lights + <Positive>	– (11) – yellow 2 – warm 1 – dark 1 – sleepy 1 – blue white lights 1	– blue white lights + <Positive> warm + <Negative> lights + <Positive>	– (31) – Bright 3 – Dark 3 – Bad 3 – Irritating 2 – Sunlight 2	– bright + <Positive> atmosphere + <Negative> darkness + <Negative> glare + <Negative> room + <Negative> sunlight + <Positive> yellow + <Positive>
Acoustics	– (40) – noisy 6 – constant 2 – silence 2 – sleep 2 – place 2	– house + <Negative> city + <Negative> quietness + <Negative> schoolchildren + <Negative> couch + <PositiveFeeling>	– (8) – peaceful 1 – not irritating 1 – play music 1 – disturbing 1 – quietness 1	– quietness + <Positive>	– (10) – open 1 – noisy 1 – window 1 – daytime 1 – sleep 1	– daytime + <Positive> sleep + <Positive>	– (18) – irritating 2 – outside 2 – earplugs 1 – washing machine 1 sharing 1	– focus + <Negative> washing machine + <Negative> outside noises + <Negative> personal noise + <Positive> sleep + <PositiveFeeling>	– (42) – noisy 3 – quiet 3 – window 2 – open 2 – music 1	– silence + <Negative> loneliness + <Negative> window + <Negative> quietness + <NegativeFeeling>
Privacy	– (29) – closed 2 – door 2 – large 1 – people 1 – share 1	– large + <Positive> places + <Positive> housemate + <NegativeAttitude>	– (16) – privacy 2 – open 1 – isolated 1 – people 1 – door 1	– people + <Positive> privacy + <Positive>	– (12) – high 1 – sound insulation 1 – playing music 1 – floor 1 – people – privacy 1	– floor + <Positive> privacy + <Positive> sound insulation + <Positive>	– (12) – closed 1 – translucent strip 1 – walking 1 – weather 1 – window 1	– weather + <Positive> window + <Negative>	– (13) – room 2 – privacy 2 – control 1 – curtains 1 – size 1	– privacy + <Positive>
Cleanliness	– (8) – order 1 – place 1 – dirt 1 – feel 1 – clean 1	– "comfort + <PositiveFeeling> – feel + <Contextual> – "	– (18) – meaningful 1 – common areas 1 – calmness 1 – objects 1 – dirty 1	– "common areas + <NegativeFeeling> – objects + <Positive> – "	– na	– na	– (2) annoyed 1 – cleaning 1	– cleaning + <Positive>	– (12) – annoyed 1 – dust 1 – smells 1 – sofa 1 – air 1	– controls + <PositiveFeeling> – kitchen + <Negative> – "
Security	– (31) – reliable 2 – flat 1 – open 1 – lock room 1 – housemates 1	– feeling + <Positive> housemates + <Positive> influences + <Negative> <	– (7) – safe 1 – bad 1 – house lock 1 – neighborhood 1 – experiences 1	– experiences + <Negative> neighborhood + <Positive>	– (21) – Reliable 1 – Feeling 1 – checkpoints 1 – housemates 1 – room 1	– feeling + <Positive> housemates + <Positive> room + <Positive>	– (6) – unconcerned 1 – door 1 – incident 1 – security 1 – feel 1	– feel + <Positive> security + <NegativeAttitude>	– (26) – open 3 – not safe 2 – checkpoints 2 – comfort 2 – valuable 1	– building + <Negative> house + <Negative> comfort + <NegativeCompetence> room + <Positive>

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TOC

TABLE APP.D.1 Text mining results

*	Concept (38)	Sentiment	Concept (30)	Sentiment	Concept (9)	Sentiment	Concept (11)	Sentiment	Concept (44)	Sentiment

* *Interview question*

How to read table:

- *The number next to each "Concept" indicates the frequency with which the concept was expressed in the answer. To shorten the table, only the top five concepts have been shown in this table.*
- *The <type> is a group of words mentioned by an interviewee generally representing an emotion. They can be positive, negative, positive feeling, negative feeling, etc. This group of words is produced by the software's built-in lexical resources.*
- *The "Sentiment" is presented in the form of "concept + <type>". Therefore it is the combination of a word mentioned by the participant and an emotion generally associated to it.*
- *The combination of "concept + <type>" (the Sentiment) gives insights into the most common way in which the participants feel about the concept in question. It gives an idea as to how the people representing the archetype feel about a certain concept.*
- *The left column indicates the question during the interview, in which the Concepts and Sentiments were expressed.*
- *The Concept and the Sentiment columns are to be read independently from each other.*
- *Example: for the question of "Light" for Archetype 1; 38 concepts were mentioned. "Dim" was the most common concept, mentioned 3 times. The concept of "activities" and positive connotations is the main sentiment about the question of light. This is interpreted as "For Archetype 1; the activities at home elicit positive emotions in relation to the lighting"*

TABLE APP.D.2 Energy readings

Cluster	4	5	2	2	5	3	4	3	4	1	5	5	1	1	1
ID Interview	14A	2C	6D	5E	11AF	4G	1H	9I	8J	13K	7L	11M	3N	10O	12P
Electricity (kwh)	420,57	352,95	617,37	169,90	617,37	95,57	895,43	65,67	617,37	131,54	247,06	80,40	97,38	773,50	461,71
Gas (m^3)	624,18	236,79	774,02	63,86	774,02	17,20	272,24	0,35	774,02	116,58	93,67	46,50	59,33	78,58	501,49

Per month per person

TABLE APP.D.3 Final questionnaire results per archetype (Mean (SD))

Pride*	3.3 (0.9)	3.1 (0.9)	3.8 (1.0)	3.8 (1.2)	2.3 (1.2)
Admiration*	2.5 (1.0)	2.6 (1.0)	2.8 (1.4)	3.1 (1.3)	1.9 (1.1)
Expectation					
Satisfaction*	3.8 (0.6)	3.4 (0.8)	4.4 (0.6)	4.3 (0.7)	2.9 (1.1)
Hope	2.7 (1.0)	3.0 (0.9)	2.8 (1.3)	3.2 (1.3)	2.6 (1.2)
Wellbeing					
Desire	3.1 (0.9)	3.1 (0.9)	3.2 (1.3)	3.4 (1.1)	2.6 (1.1)
Joy*	3.7 (0.7)	3.4 (0.7)	4.2 (0.7)	4.1 (0.9)	3.0 (1.1)
Material					
Fascination*	2.6 (1.1)	3.0 (1.0)	3.4 (1.3)	3.7 (1.3)	2.3 (1.3)
Negative emotions					
Social					
Shame*	1.4 (0.7)	2.1 (1.0)	1.2 (0.4)	1.3 (0.7)	1.9 (1.1)
Contempt	1.3 (0.5)	1.8 (0.9)	1.1 (0.4)	1.3 (0.7)	1.6 (0.9)
Expectation					
Dissatisfaction*	1.8 (0.8)	2.5 (1.0)	1.3 (0.6)	1.5 (0.9)	2.8 (1.3)
Fear	1.4 (0.7)	1.8 (0.9)	1.2 (0.5)	1.3 (0.8)	1.6 (0.9)
Wellbeing					
Disgust*	1.4 (0.7)	2.1 (1.0)	1.1 (0.5)	1.1 (0.4)	2.0 (1.1)
Sadness	1.3 (0.6)	2.0 (1.0)	1.2 (0.6)	1.4 (0.8)	1.8 (1.1)
Material					
Boredom*	1.8 (0.8)	2.5 (1.1)	1.4 (0.7)	1.6 (0.9)	2.3 (1.3)
Environmental Affordances – mean (SD)					
Sensorial					
Adequate temperature	3.8 (0.9)	3.3 (1.1)	3.6 (1.1)	4.0 (1.1)	3.6 (1.1)
Air freshness	3.8 (1.3)	3.5 (1.3)	3.7 (1.3)	4.3 (1.2)	3.6 (1.4)
Lighting quality*	3.8 (0.8)	3.3 (0.9)	3.7 (0.9)	4.2 (0.9)	3.8 (1.1)
Acoustical quality	3.5 (1.1)	3.1 (1.1)	3.5 (1.2)	4.2 (1.0)	3.5 (1.2)
Cleanliness and orderliness	3.9 (0.8)	3.5 (1.0)	3.7 (1.1)	4.3 (1.0)	3.5 (1.1)
Psychological					
Freedom of interaction*	4.0 (0.8)	3.6 (0.8)	3.7 (0.9)	4.7 (0.6)	4.0 (1.1)
Control of systems*	3.4 (0.9)	3.2 (0.8)	3.3 (1.2)	4.5 (0.8)	3.3 (1.4)
Freedom of being*	3.9 (0.9)	3.7 (0.9)	3.6 (1.2)	4.6 (0.8)	3.5 (1.3)
Privacy*	4.2 (0.7)	3.8 (0.9)	3.9 (1.0)	4.7 (0.7)	3.6 (1.3)
Spatial quality (layout and size)*	3.9 (0.8)	3.3 (0.9)	3.4 (1.0)	4.6 (0.8)	3.7 (1.3)

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TABLE APP.D.3 Final questionnaire results per archetype (Mean (SD))

Control – mean (SD). 1: Strongly disagree; 5: Strongly agree.	C1	C2	C3	C4	C5
Internal control					
Freedom of action*: I am able to do everything I want in my home, in accordance to my personal ideas.	3.7 (0.9)	3.1 (1.0)	4.1 (1.1)	4.5 (0.9)	3.2 (1.3)
Privacy*: The feeling of privacy in my home is entirely determined by myself.	3.0 (0.9)	2.7 (1.1)	3.1 (1.3)	3.8 (1.4)	2.8 (1.3)
Spatial: Regardless of the size of my home, I can make myself comfortable there.	3.7 (0.9)	3.5 (0.9)	4.1 (1.0)	4.1 (1.3)	3.5 (1.4)
Order and cleanliness*: It is up to me whether my home environment is kept in a tidy and clean state.	4.1 (0.8)	3.7 (1.0)	4.2 (0.9)	4.8 (0.5)	4.1 (1.2)
Climate*: I carefully control the temperature of my home to keep me comfortable.	2.9 (1.0)	2.6 (1.2)	3.0 (1.3)	3.7 (1.5)	2.6 (1.5)
Relaxation*: I am able to de-stress at home whenever I want.	3.6 (0.8)	2.8 (1.0)	3.5 (1.3)	4.3 (1.1)	3.5 (1.4)
Atmosphere*: It is up to me whether or not I make the atmosphere I want in my home.	3.5 (0.8)	3.0 (1.0)	3.6 (1.0)	4.4 (1.0)	3.5 (1.3)
Personalization*: The way my home looks and feels reflects my personality.	3.6 (0.7)	3.1 (1.0)	3.8 (0.8)	4.6 (0.9)	3.4 (1.3)
Mood: I make an effort to get the right mood in my home.	3.7 (0.8)	3.3 (0.9)	3.9 (0.9)	4.4 (0.9)	3.6 (1.2)
External control					
Freedom of action: To a great extent, I do not plan the actions and activities that I carry out in my home.	3.1 (0.9)	2.8 (1.0)	2.4 (1.3)	2.7 (1.5)	3.2 (1.3)
Privacy*: Whether or not my home offers me the sense of privacy depends on fortunate circumstances.	2.6 (0.9)	2.4 (1.0)	1.6 (1.0)	1.8 (1.2)	2.4 (1.3)
Spatial: Feeling comfortable in my home is a matter of the layout and size of my house.	2.7 (0.9)	2.6 (1.0)	2.3 (1.2)	3.1 (1.6)	2.9 (1.4)
Order and cleanliness*: I can't completely control the cleanliness of my home: they are the result of time.	2.7 (0.9)	2.6 (1.2)	1.8 (1.1)	2.3 (1.6)	3.0 (1.4)
Climate*: The temperature in my home is pretty much determined by the house itself.	3.2 (0.9)	2.8 (1.1))	2.2 (1.2)	2.4 (1.5)	3.5 (1.4)
Relaxation*: Having a stress-free environment in my home is all luck: I cannot influence it.	2.4 (0.9)	2.4 (1.1)	1.6 (1.2)	2.2 (1.4)	2.4 (1.3)
Atmosphere*: The atmosphere in my home is the way it is, without me doing anything about it.	2.6 (0.8)	2.7 (1.1)	1.9 (1.1)	2.0 (1.3)	2.7 (1.3)
Personalization*: It is only a coincidence whether my home seems to reflect my personality or not.	2.6 (0.9)	3.1 (1.0)	1.9 (1.3)	2.1 (1.5)	2.5 (1.4)
Mood*: The mood of my home is something that just happens by itself.	2.8 (0.9)	2.7 (1.2)	2.4 (1.3)	2.6 (1.5)	2.7 (1.4)
Habits – I need to use energy for X behaviour, no matter what: n (%)	**C1**	**C2**	**C3**	**C4**	**C5**
Self-Growth					
Relax	56 (25.0)	47 (27.6)	36 (26.3)	39 (34.5)	31 (26.5)
Personalize the place	24 (10.7)	31 (18.2)	36 (26.3)	19 (16.8)	23 (19.7)
Socialize in person	70 (31.3)	43 (25.3)	43 (31.4)	39 (34.5)	38 (32.5)
Do my hobbies	62 (27.7)	63 (37.1)	49 (35.8)	42 (37.2)	41 (35.0)
Coziness					
Warm up	148(66.1)	115 (67.6)	100 (73.0)	70 (61.9)	74 (63.2)
Feel privacy	24 (10.7)	26 (15.3)	18 (13.1)	17 (15.0)	12 (10.3)
Create a mood	63 (28.1)	88 (51.8)	82 (59.9)	62 (54.9)	48 (41.0)
Restorers					
Clean up	106 (47.3)	90 (52.9)	81 (59.1)	52 (46.0)	57 (48.7)
Socialize online	104 (46.4)	109 (64.1)	96 (70.1)	77 (68.1)	59 (50.4)
Freshen up	119 (53.1)	94 (55.3)	85 (62.0)	60 (53.1)	61 (52.1)
Cook	184 (82.1)	144 (84.7)	111 (81.0)	95 (84.1)	93 (79.5)

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TOC

TABLE APP.D.3 Final questionnaire results per archetype (Mean (SD))

Attitudes towards energy– mean (SD)	C1	C2	C3	C4	C5
Behavioural intentions - 1:Definitely yes - 5:Definitely not					
Willingness to change behaviour to use less energy	2.0 (0.8)	2.1 (0.8)	2.0 (0.9)	1.8 (0.8)	2.0 (0.9)
Willingness to live with less comfort to save energy	3.0 (1.0)	3.0 (0.9)	2.8 (1.1)	3.0 (1.1)	3.1 (1.0)
Social comparison attitudes towards energy use – 1:much more than others 5: much less than others					
Space heating	3.4 (1.0)	3.5 (1.1)	3.3 (1.1)	3.3 (1.1)	3.1 (1.1)
Water heating	3.0 (0.7	3.2 (0.8)	3.1 (0.9)	2.8 (0.8)	2.9 (0.7)
Use of energy-consuming products	3.1 (0.7)	2.0 (0.8)	3.2 (0.9)	3.1 (0.7)	2.9 (0.8)
Actual expenditure knowledge; Yes, I know – n (%)					
Electricity	31 (14.2)	16 (9.4)	38 (27.7)	23 (20.4)	11 (9.4)
Gas	25 (11.4)	17 (10.0)	29 (21.2)	22 (19.5)	11 (9.4)
Health in the last 12 months n (%)	**C1**	**C2**	**C3**	**C4**	**C5**
Asthma	10 (4.7)	9 (5.3)	6 (4.4)	2 (1.8)	3 (2.6)
Bronchitis/bronchial pneumonia	13 (6.1)	6 (3.5)	6 (4.4)	5 (4.4)	1 (0.9)
Wheezing or whistling in the chest	16 (7.6)	16 (9.4)	11 (8.0)	9 (8.0)	6 (5.1)
Other chest condition	8 (3.8)	7 (4.1)	2 (1.5)	4 (3.5)	6 (5.1)
Hay fever	47 (22.2)	38 (22.4)	26 (19.0)	21 (18.6)	28 (23.9)
Allergic rhinitis	85 (40.1)	60 (35.5)	33 (24.1)	36 (31.9)	45 (38.5)
Eczema	19 (9.0)	26 (15.3)	16 (11.7)	10 (8.8)	15 (12.8)
Dermatitis	7 (3.3)	8 (4.7)	5 (3.6)	5 (4.4)	3 (2.6)
Other skin conditions	30 (14.2)	21 (12.4)	12 (8.8)	11 (9.7)	16 (13.7)
High lipids in the blood	6 (2.8)	8 (4.7)	7 (5.1)	5 (4.4)	4 (3.4)
Diabetes	1 (0.5)	2 (1.2)	0 (0.0)	1 (0.9)	1 (0.9)
High blood pressure	9 (4.2)	5 (2.9)	7 (5.1)	4 (3.5))	3 (2.6)
Heart conditions	1 (0.5)	5 (2.9)	1 (0.7)	3 (2.7)	0 (0.0)
Migraine	42 (19.8)	20 (11.8)	19 (13.9)	18 (16.1)	21 (17.9)
Depression	15 (7.1)	26 (15.3)	10 (7.3)	12 (10.6)	17 (14.5)
Anxiety	34 (16.0)	38 (22.4)	15 (10.9)	13 (11.5)	26 (22.2)
Psychiatric problems	7 (3.3)	14 (8.2)	3 (2.2)	0 (0.0)	7 (6.0)
Other problems	27 (12.7)	21 (12.4)	10 (7.3)	11 (9.9)	15 (12.8)
Symptoms while at home - At least once every 2-3 weeks					
Related to indoor environment (yes and partly)					
Dry Eyes	23 (5.6)	19 (14.5)	3 (4.2)	4 (5.0)	11 (9.6)
Itchy or watery eyes	13 (3.9)	17 (13.9)	5 (9.9)	3 (3.7)	10 (8.0)
Blocked nose	40 (18.8)	26 (26.3)	5 (10.7)	9 (14.2)	27 (25.7)
Runny nose	28 (12.9)	17 (15.9)	5 (10.4)	12 (18.8)	18 (16.9)
Sneezing	47 (23.5)	27 (29.3)	11 (23.8)	14 (21.1)	27 (27.2)
Dry throat	30 (11.6)	19 (16.8)	7 (12.9))	6 (7.1)	13 (11.2)
Lethargy	17 (8.3)	16 (17.7)	3 (6.7)	6 (9.8)	19 (19.1)
Headaches	9 (4.1)	10 (9.4)	3 (5.2)	2 (2.8)	7 (6.3)
Dry. itchy. irritated skin	16 (5.2)	11 (8.9)	7 (13.3)	14 (17.4)	17 (11.6)
Breathing difficulty	7 (1.1)	7 (2.3)	0 (0.0)	12 (12.4)	3 (1.2)
Other symptoms	55 (2.0)	2 (0.4)	8 (1.9)	0 (0.0)	3 (0.5)

>>>

TABLE APP.D.3 Final questionnaire results per archetype (Mean (SD))

Building	C1	C2	C3	C4	C5
Building type n (%)					
Apartment	43 (21.8)	23 (27.1)	5 (11.9)	22 (38.6)	25 (26.6)
Gallery apartment (with main door in a common external corridor)	25 (12.7)	14 (16.5)	6 (14.3)	9 (15.8)	16 (17.0)
Row house (with shared side walls)	62 (31.5)	29 (34.1)	15 (35.7)	13(22.8)	20 (21.3)
Semidetached house (sharing one common wall)	36 (18.3)	4 (4.7)	12 (28.6)	9 (15.8)	18 (19.1)
Detached house (free-standing)	14 (7.1)	6 (7.1)	3 (7.1)	3 (5.3)	6 (6.4)
Other	17 (8.6)	9 (10.6)	1 (2.4)	1 (1.8)	9 (9.6)
Occupants					
Number of people living in same house*					
Over age of 18 – mean (SD)	4.7 (4.9)	6.0 (7.4)	4.2 (4.2)	2.5 (2.1)	5.1 (9.9)
Under age of 18 – mean (SD)	0.9 (1.2)	1.2 (2.8)	1.1 (1.5)	1.6 (3.3)	1.3 (1.9)
Type of occupant*					
Family members	55 (27.9)	16 (18.8)	16 (38.1)	9 (15.8)	15 (16.0)
Housemates	93 (47.2)	56 (65.9)	14 (33.3)	21 (36.8)	54 (57.4)
(Un)married couple	24 (12.2)	4 (4.7)	4 (9.5)	9 (15.8)	11 (11.7)
Alone	25 (12.7)	9 (10.6)	8 (19.0)	18 (31.6)	14 (14.9)
*not asked to TNW					
Tenure*					
Owner	48 (24.5)	13 (15.3)	15 (36.6)	13 (22.8)	10 (10.8)
Renter	148 (75.5)	72 (84.7)	26 (63.4)	44 (77.2)	83 (89.2)
*not asked to TNW					
Time residing in the house					
Less than 6 months	42 (21.3)	19 (22.4)	15 (35.7)	33 (57.9)	38 (40.4
6 to 12 months	31 (15.7)	17 (20.0)	6 (14.3)	8 (14.0)	12 (12.8
1 - 5 years	77 (39.1)	34 (40.0)	10 (23.8)	10 (17.5)	34 (36.2
More than 5 years	44 (22.3)	14 (16.5)	11 (26.2)	5 (8.8)	9 (9.6)
Building dimensions					
Area – square meters (SD)	113.0 (116.0)	126.8 (108.8)	127.8 (95.3)	80.0 (67.1)	99.5 (116.0)
Number of rooms (SD)	3.9 (1.4)	4.3 (1.2)	4.1 (1.3)	3.4 (1.5)	3.7 (1.5)
Characteristics	**C1 - 224 (29.4)**	**C2 – 170 (22.3)**	**C3 – 137 (18.0)**	**C4– 113 (14.8)**	**C5- 117 (15.4)**
Groups					
TNW	26 (11.6)	85 (50.0)	95 (69.3)	55 (48.7)	23 (19.7)
SGR	39 (17.4)	4 (2.4)	11 (8.0)	13 (11.5)	16 (13.7)
TE4	113 (50.4)	51 (30.0)	15 (10.9)	11 (9.7))	34 (29.1)
IS1	25 (11.2)	10 (5.9)	4 (2.9)	2 (1.8)	3 (2.6)
IS2	4 (1.8)	13 (7.6)	8 (5.8)	4 (3.5)	14 (12.0)
IS3	17 (7.6)	7 (4.1)	4 (2.9)	28 (24.8)	27 (23.1)
Personal					
Gender					
Men	116 (51.8)	105 (61.8)	63 (46.7)	54 (48.2)	60 (51.3)
Women	106 (47.3)	65 (38.2)	72 (53.3)	58 (51.8)	57 (48.7)
Age (years)					
Mean (SD)	25.4 (9.0)	27.3 (9.3)	33.9 (12.8)	32.8 (12.5)	26.1 (8.5)
Range	18-63	18-63	18-74	19-64	18-63

>>>

TABLE APP.D.3 Final questionnaire results per archetype (Mean (SD))

Highest education level					
Primary or Secondary school	94 (42.2)	61(35.9)	20 (14.6)	15 (13.3)	37 (31.6)
Some college	2 (0.9)	2 (1.2)	0 (0.0)	3 (2.7)	0 (0.0)
Completed Bachelors	26 (11.7)	13 (7.6)	13 (9.5)	28 (24.8)	36 (30.8)
Completed Masters	66 (29.6)	73 (42.9)	75 (54.7)	48 (42.5)	27 (23.1)
Doctorate	27 (12.1)	2 (1.2)	6 (4.4)	4 (3.5)	10 (8.5)
Professional	8 (3.6)	19 (11.2)	21 (15.3)	14 (12.4)	7 (6.0)

** variables making up the final clustering model*

APPENDIX E

Sensitizing Booklet

TOC

Comfort

a 7-day activity booklet

Dear Participant,

In this book you have 7 activities that you need to do every day, during the next week.

Each activity takes no more than 5 to 10 minutes. You will make use of the stickers and materials provided.

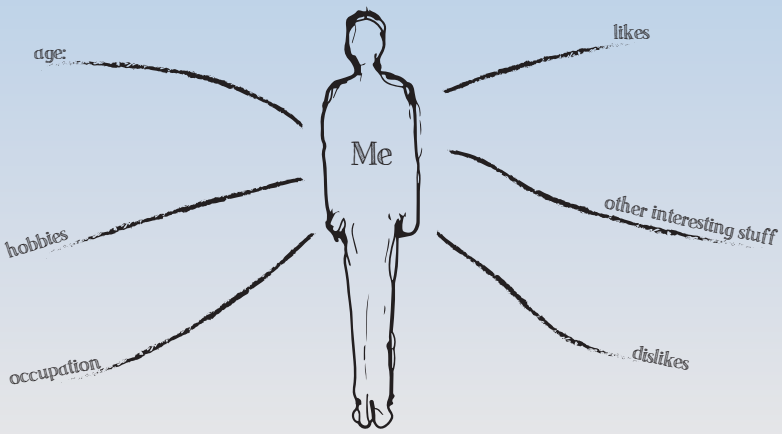
The purpose of the booklet is to start immersing you in the topic of the upcoming focus group session in which you will participate.

As a result, it is important that you fill it out, because one of the activities will be the opening discussion in the session!.

Thank you for your ideas!

Day 1: You

Give us a quick explanation of who you are.
How old are you, what do you do, what do you like, what do you dislike...



Day 2: Snip and Stick

Look in the package that you received for the list of words.
Snip them with a pair of scissors and glue them in similar categories. Stick the most important ones for you closer to the word Comfort.
Look in the back of the word list for an example.

Comfort

TOC

Day 3: Diary

Please fill out this diary of the activities you do. It is best if you can combine weekdays and weekdays. Start with your wake-up time, and include hours outside the house. Finish with your bed time.

TimeStart of activity	Time End of activity	Give a brief description of the task you did. Tell what consumer products you used and in which room of the house you were. Tell the trigger that told you to do start, and the reward you get from doing this activity. You can skip rows if you need more space.
Wake up time		
Bed time		

Day 4: Diary

TimeStart of activity	Time End of activity	Give a brief description of the task you did. Tell what consumer products you used and in which room of the house you were. Tell the trigger that told you to do start, and the reward you get from doing this activity. You can skip rows if you need more space.
Wake up time		
Bed time		

Day 5: Diary

Time Start of activity	Time End of activity	Give a brief description of the task you did. Tell what consumer products you used and in which room of the house you were. Tell the trigger that told you to do start, and the reward you get from doing this activity. You can skip rows if you need more space.
Wake up time		
Bed time		

Day 6: Reflection

Reflect on the activities of your diary, and tell which of those are comfort-related activities.

Day 7: Storytelling

Please write down a particular episode/routine/action/event of your recent or distant past, that you associate with being comfortable. Write it in the 3rd person (he or she). Be as detailed as possible, but describe it as an outsider. Explain in detail about the context: when does it happen, what do you use, who else is there, what triggers it, how is the full process. Focus on the emotions you feel as the event unfolds. Drawing a timeline can be useful.
You can support your story with drawing, images, or stickers.



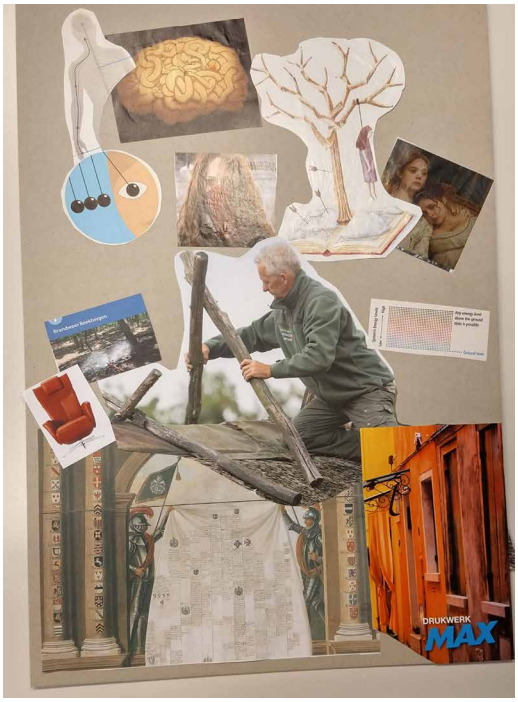
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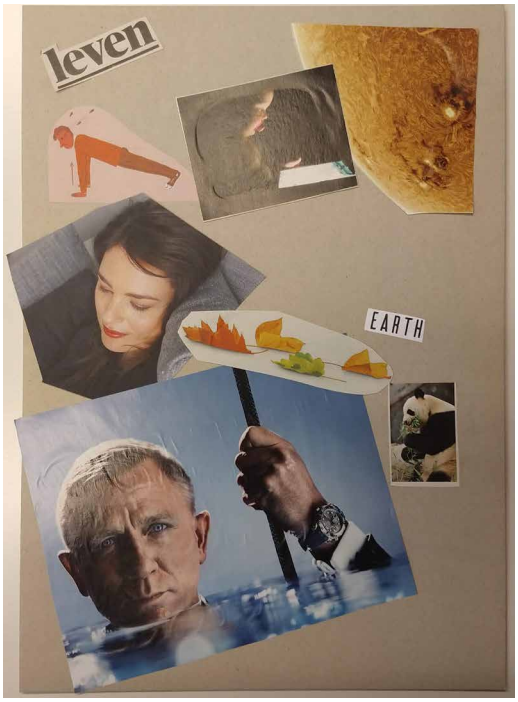
APPENDIX F

Meaning of energy use at home



TOC

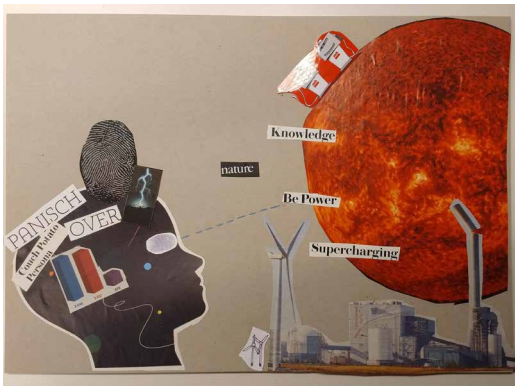

DRUKWERK
MAX

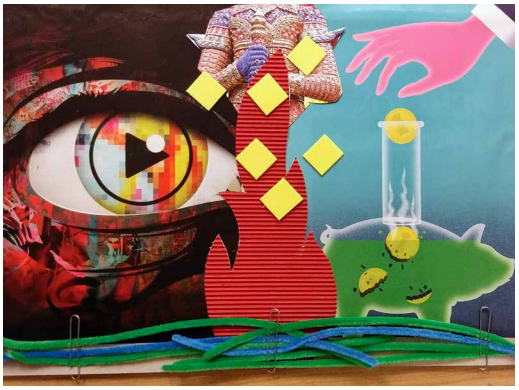

leven
EARTH


50% korting


DRUKWERK
MAX
135 GR
MAT
de vlucht

TOC


Knowledge
nature
Be Power
Supercharging
PANISCH
OVER



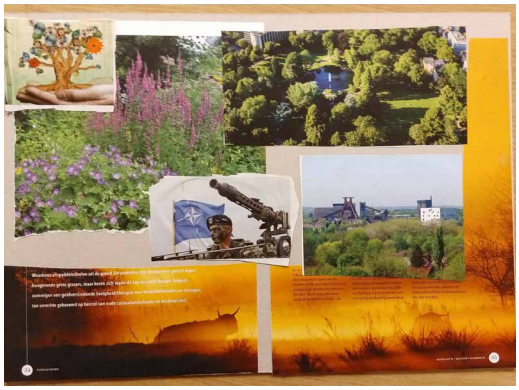

Time
is
running
OUT!


Cocktails
&
Dreams

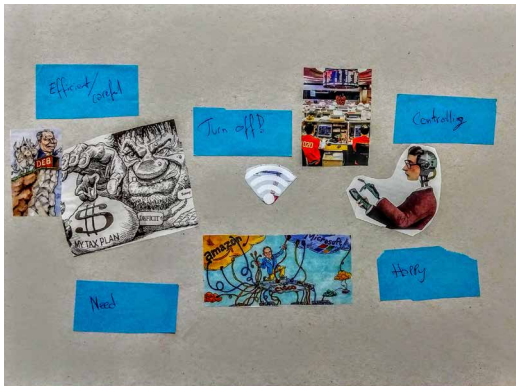



CLIMATE CHANGE
BY 2030
INNOVATION
CHANGE SYSTEM
WE ASK YOU

TOC

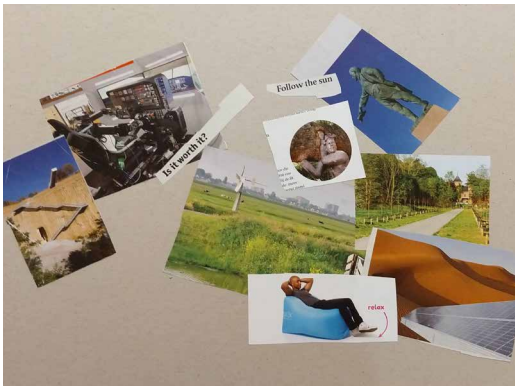



Data and the new rules of competition
SCALE
COMFORTABLE
BRIT 1


Efficient/ careful
Turn off!
Controlling
MY TAX PLAN
amazon
Horny
Need




pharosreizen
5972
Time
Money
A series of unfortunate events


Follow the sun
Is it worth it?
relax

TOC

APPENDIX G

Ideal Home Experience



TOC







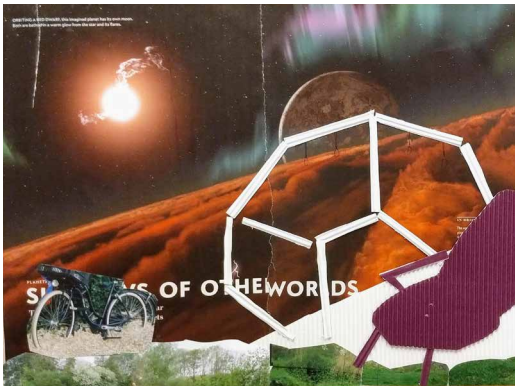


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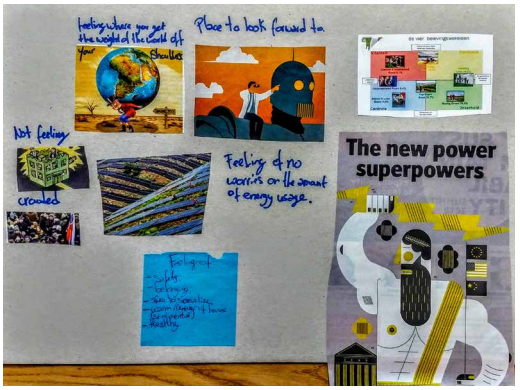




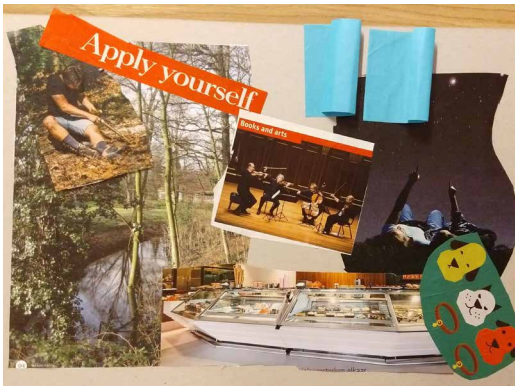


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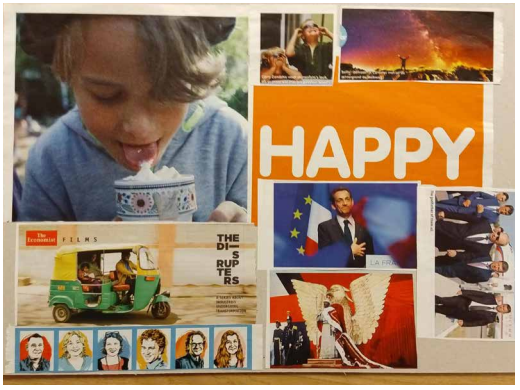

PERFECT ORIENTED
60
PROTECTED
technology
STRANGE
CONNECTED NATURE
AUTOMATED
EVERYTHING CONNECTED


Feeling where you get the weight of the world off your shoulder
Place to look forward to
Not feeling
crowded
Feeling of no worries or the smart of energy usage.
The new power superpowers




Apply yourself
Books and arts


26


HAPPY
FILMS
THE DISRUPTERS

TOC

TOC

Curriculum Vitae

Marco A. Ortiz

Date of Birth: 30 July 1986
Place of Birth: Mexico City, Mexico

Education

2015 - 2019	PhD candidate, Chair of Indoor Environment, TU Delft.
2011 - 2014	MSc. Design for Interaction. Specialization in Retail Design, TU Delft.
2008 - 2011	Magna cum Laude BA in Environmental Design, Specialization in Architecture and Studio Arts. State University of New York at Buffalo, New York.
2006 - 2008	Associate's Degree in Engineering Science. Broome Community College, Binghamton, New York.

Professional Experience

08.2014 - 08.2015	Self-employed customer researcher and concept developer.
08.2013 - 04.2014	Culinary and customer values researcher. Master Thesis. Nordic Food Lab (noma), Copenhagen, Denmark.
02.2012 - 07.2012	Internship customer research. G-Start RAW, Amsterdam, Netherlands.
01.2011 - 06.2011	Historic and archaeological research. Buffalo Archaeological Survey, Buffalo NY.
07.2010 - 12.2010	Urban and regional planning research. Benderson Development, Buffalo, NY.

Academic Experience

2017	Tutoring MSc.Student final project, TU Delft.
SINCE 2016	Technoledge Climate design student tutoring, TU Delft.
SINCE 2016	Yearly lecture Innovation and Sustainability, TU Delft.

Memberships

SINCE 2009	Sigma Alpha Pi National Honour Society.
SINCE 2008	Tau Sigma National Honour Society.

Honours and Awards

12.2015	Winner of best Design Award Master Thesis. Jan Wolf Prize. Slow Food Nederland.
06.2013	Winner of LEGO Retail Design Challenge.
2010 AND 2011	Dean's List of SUNY Buffalo.

Publications

2019

Bluyssen, P.M., Zhang, D., Kim, DH., Eijkelenboom, A., Ortiz Sanchez, M. First SenseLab Studies with primary school children: exposure to different environmental configurations in the Experience room. *Intelligent Building International.* DOI: https://doi.org/10.1080/17508975.2019.1661220

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Ortiz Sanchez, M., Kurvers, S. R., & Bluyssen, P. M. (2017). A review of comfort, health, and energy use: Understanding daily energy use and wellbeing for the development of a new approach to study comfort. *Energy and Buildings*, 152, 323-335.

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2016

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Ortiz Sanchez, M., Kim DH., & Bluyssen P. M. (2019). Substantiation of Home Occupant Archetypes with the Use of Generative Techniques: Analysis and Results of Focus Groups. B*uilding Information & Technology, submitted.*

TOC



19#05

Home Occupant Archetypes

Profiling home occupants' comfort- and energy-related behaviours with mixed methods

Marco A. Ortiz

This research aimed at understanding how occupants use energy in their homes to make themselves feel more comfortable. This was done to propose customized environmental characteristics that could improve the occupants' comfort while reducing energy consumption. To conceptualize such bespoke environmental features, occupant archetypes were produced based on the occupants' intentions and motivations behind comfort behaviours.

A mixed-methods human-centered design approach was developed for which four steps were required: 1- development of a specialized questionnaire; 2- administration of the questionnaire and statistical clustering of respondent; 3- field visits with indoor environmental monitoring and building data gathering; and 4- focus groups to find out the meaning of using energy and of an ideal comfortable home for each archetypal occupant.

Both qualitative and quantitative data were used to complete the statistical clusters, in order to develop the five final archetypes that are summarized as follows:

Restrained Conventionals are conservative users and concerned about finances, need home openness, social interaction, but also privacy. Incautious Realists, need modularity of the home spaces, to have a feeling of safety. The Positive Savers need spaces and surfaces that allow for cleanliness and orderliness and have energy frugal tendencies. The Sensitive Waster pays attention to the indoor climate, tactile sensations, and need to have the feeling of freedom in their house, while being a high energy spender. Vulnerable Pessimists emphasise owning a visually aesthetic house, while wanting smart technologies in it; they also appreciate the sense of community and of belonging to the neighbourhood.

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