Research Plan:

A heat pump decision tool for homeowners

An advise leading to the benefits of the homeowner and a contribution to the energy transition of the built environment

Master thesis *Building Technology* – Stephan Kolman – TU Delft – October 2022

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1.1 Background

The Netherlands is currently in the middle of an energy transition, the large scale combustion of fossil fuels around the world lead to a CO_2 increase in the atmosphere, which caused temperature increase (global warming) on the planet. Environmental policies aim to phase out the use of fossil fuels entirely (van Leeuwen, De Wit, & Smit, 2017). In 2015 the united nations signed the Paris Agreement. The Paris Agreement had three stated objectives: (1) to grip the increase in global average temperature to "well below" 2° C above pre-industrial levels; (2) to increase the ability to adapt to the negative impacts of climate change; and (3) to make financing flows consistent with both of the above. The goal is to reduce the greenhouse gas emissions as soon as possible and to reach emission neutrality in the second half of this century (Horowitz, 2016). To do so the united nations had to make changes in their national policies and regulations. In the Netherlands this resulted in the Dutch climate agreement (klimaatakkoord) in 2019. This is the Dutch elaboration of the international Paris Agreement. One of the agreements is that 30 ergoregions in the Netherlands investigate where and how sustainable energy can be generated the best. And also which heat sources can be used to disconnect neighbourhoods and buildings from the gas network ("Nationaal Programma,"). The climate agreement states that the Netherlands is at the start of the energy transition of the built environment. 7 million households and 1 million buildings, which are currently poorly insulated and almost all heated with natural gas need to be transformed to well insulated buildings, which are heated with sustainable heat and electricity from renewable sources (*Klimaatakkoord*, 2019).

The Dutch building sector has to contribute to minimize the effect of global warming and climate change. Various measures have been taken in order to ensure this. The building sectors introduces every year lower energy performance coefficients for new buildings by tightening the building standards (Camarasa et al., 2018). Government-supported large scale energy renovations such as 'stroomversnelling' and 'energiesprong' for existing houses are performed (Camarasa et al., 2018). Subsidy schemes are provided from the government for heat from renewable sources, such as heat pumps and district heating projects based on waste heat streams and renewable sources (van Leeuwen et al., 2017).

1.2 Problem statement

With the measures and incentives as stated in 1.1 background the Dutch government is phasing out the use of natural gas, they encourage homeowners to change the way their homes are being heated and change the homes heating system to a sustainable heating system, for example a heat pump.

Heat pump manufacturers and independent organisation are responding to these government measures and the energy transition by making online heat pump decision tools. These heat pump tools can be used by homeowners to check whether a heat pump system can be used in their home. Heat pump manufacturers often do this out of self-interest in order to sell more heat pumps. Independent organizations are doing this more in interest of the energy transition. The tool being designed in this thesis is an independent heat pump decision tool, with the aim of making a major contribution to the energy transition by any homeowner who uses the tool. On top of that they will also experience a better living comfort in their home.

The difficulty in designing such a tool is that every home is different, every home has different characteristics, different spatial aspects (indoors and outdoors) and a different dimensioned heat emission system. On top of that every home has different energetic quality, since homes can be post-insulated over the years. The purpose of the tool is to be able to map all these aspects of a specific home and then provide a targeted advice in all these areas before a heat pump system can be applied.

Existing heat pump decision tools will be analysed in order to determine how they collect all the necessary information by questioning the homeowner. The shortcomings of existing tools will be improved in the final tool.

In order to be able to provide independent advice to the homeowner who utilizes the tool, the overall energy issue based on space heating must be first mapped out. The possible solutions and sustainable energy systems must be discussed, which will serve as advice in the final tool.

2.1 Main research question

The goal of this thesis is:

Mapping the current energy problems in the Netherlands related to space heating. In addition, discussing solutions for possible other sustainable alternatives for space heating. Then integrate these findings into an independent heat pump decision tool for homeowners. By using this tool, the homeowners receive advice with all the important aspects that come with it before they engage an installer to install a heat pump. The goal is that the advice that the homeowner receives has a major contribution to the energy transition of the built environment and the living comfort of the homeowner himself.

In order to achieve this goal, the following main question has been formulated:

How is a heat pump decision tool for homeowners with limited technological knowledge designed, which gives an advice that contributes to the energy transition of the built environment and which provides an advice on which heat pump system and additional measures a homeowner should consider before engaging an installer?

2.2 Research sub-questions

In order to collect the necessary information to answer the main research questions, the research will be divided into three consecutive parts with each part having its own sub-questions.

Research part 1: 'Theoretical framework'

What are the current energy usages and energy sources of the built environment for in particular space heating of households in the Netherlands, what problems do they cause and what are potential renewable energy sources? (chapter 1)

What policies are already introduced to support the energy transition of the built environment and what are their influences on the built environment and how can these be important in the design of the heat pump decision making tool? (chapter 2)

What heat pump systems are integrated in existing building renovation cases and which envelope improvements are performed and can these techniques be used for the advice in the final heat pump decision tool? (chapter 3)

What heat pump systems and other sustainable heating sources have potential in supporting the energy transition of the built environment and which will be included in the heat pump decision tool? (chapter 4)

Research part 2: 'Empirical research'

What aspects from the analysed existing heat pump decision tools should be combined in the new tool and which aspects remained missing in the existing tools which needs to be included in the new tool? (chapter 5)

What are the boundaries of the selected heat pump systems leading to certain advice formation of the heat pump decision tool? (chapter 6)

In what way can the heat pump decision tool fulfill an educational function for the benefit of the homeowner in terms of insulation, cost and indoor comfort and how can it contribute to the energy transition of the built environment? (chapter 7)

Research part 3: 'Research by design'

How is the heat pump decision tool designed? (chapter 8)

3.1 Scope definition

Because the advice of the tool must contribute to the energy transition, the current problems regarding this energy transition are first mapped out. In addition, measures that offer of possible solution are mapped out, which then serve as an advisory body in the tool. Renewable energy systems and heat pump systems that contribute to the energy transition are also examined and it is determined why they will or will not be used in the tool.

In addition, it is investigated which measures must be taken for the integration of a heat pump system into existing buildings and which complications arise, in order to subsequently find a solution for these complications and draw the homeowners attention to this.

In addition, research is being conducted into existing heat pump decision tools and their shortcomings so that these shortcomings can be tackled, which ultimately leads to a better tool than the ones already exist.

Initially the goals was to make the tool applicable to all housing type, but during the design it turned out that too many parameters would have to be used, which would make this thesis too long. Eventually the tool was limited to owner-occupied homes, in form of ground-level homes, which could be an terraced-house, semi-detached house, or detached house.

The tool must have an educational function for the home owner, every decision moment must offer advice and alternatives, both in the field of energetic quality (insulation), the heat emission system, and the heat pump systems that are applicable based on spatial aspects. The aim is to provide the homeowner with all the necessary information before calling an installer or contractor.

4. Added value of research

4.1 Relevance

Societal relevance

Heat pump systems are a hot topic in the Netherlands. By simple googling ‘warmtepomp’ a ton of a current news articles pop up on Google. A short selection of different articles is provided:

‘’Experts see heat pumps as one of the key solution for tackling CO_2 emissions associated with keeping buildings warm’’ (Wit, 2022).

Research by Milieu Centraal shows that one of the biggest challenges in the Netherlands is still the familiarity of the heat pump system. Two in ten homeowners have never heard of a hybrid heat pump. Three in ten have heard of it, but don’t know what it is. A fifth also think that there is no subsidy for it, and half of the people don’t know that there is subsidy (Wit, 2022).

The war in Ukraine has created uncertainty about gas prices and the supply thereof. Installer of heat pumps also notice this. Since the outbreak of the war, they have been getting more questions about heat pumps. This is reported by the sector organization Techniek Nederland ("VRAAG NAAR WARMTEPOMP NEEMT FORS TOE DOOR OORLOG IN OEKRAÏNE," 2022).

Suddenly there is a rise energy costs. What else is all this going to do? And suddenly there is an increase in the subsidy amounts. A heat pump in new buildings is indispensable, but what about existing buildings? Today, everyone already wanted a heat pump yesterday. But installing a heat pump in an existing building is harder (Driel, 2022).

The current chain of home interventions for private individuals falls short providing comprehensive and sensible advice on an individual basis. Digital tools can work, but are either expensive or not very accurate. This has a paralyzing effect on private individuals and hinders a neighbourhood approach. Tenants and owners live together and the image quality in the neighbourhood must be monitored ("Naar betere betaalbaarheid in aardgasvrije wijken: hoe gemeenten beter kunnen profiteren van recente innovaties," 2019).

According to these small selection of new articles there is a big societal relevance in designing a heat pump decision tool, which is understandable home owners who have limited knowledge and still provide an in depth advise.

Scientific relevance

Many previous studies are performed on selecting a heat pump system. The two studies from (Hepbasli & Kalinci, 2009) and (Zhang, Wang, & Wu, 2007) are based on the technological performance of such heat pump systems. (Gustafsson, 2000) proposed a method to calculate the most economical size for hybrid heat pump in a residential building in Sweden. His approach is based on static calculations. Previous studies on the choice of heating systems have focused on household characteristics, income strongly affects investment behaviour for heating system as is conducted in this study by (Nesbakken & Strøm, 1993). According to a study of (Janssen & Jager, 2002) people think about other alternatives when they are not satisfied with their current system. However none of these researches talked about the practical integration of heat pump systems in the existing building stock. The result of this thesis will link to the practical integration combined with the technological performance of the heat pump systems in the existing building stock.

As a result from the research provided by (Decuypere, Robaeyst, Hudders, Baccarne, & Van de Sompel, 2022) who conducted in-depth interviews, with a focus on the installation of heat pump technology, and identified a series of barriers that intermediaries experience when installing heat pumps. Those drivers and barriers resulted in a framework with four concrete propositions that face similar challenges in the transition to climate neutral buildings: (1) *Intermediaries should be aided and* supported *in recommending heat pumps to private homeowners,* (2) *Inform, guide, and sensitize intermediaries about up-to-date heat pump installations,* (3) *Sensitize homeowners by providing non-complex information in a centralized and accessible place,* (4) *Facilitate knowledge transfer between intermediaries who offer their services to the same consumers, transcending time.* The result of this thesis will fill in this gap. The heat pump decision tool will help the intermediaries by supporting in recommending heat pumps to homeowners. The tool will help homeowners by providing non-complex information in a centralized and accessible place (online).

Applicability in practice

The findings of this thesis will be valuable for homeowners in practice. However, it will also be valuable for the Netherlands in general as it will help the energy transition of the existing building stock. It is as well valuable for heat pump installers and suppliers as more systems are getting installed in the existing building stock. This thesis is written in the advantage of the homeowner, but in the end a lot of parties contribute from the findings from this thesis.

Personal motivation

I am working for 6 years in a heating wholesaler, so I am familiar with the practical integration of heating systems in the existing building stock, almost all of the heating systems sold are still traditional gas boilers by the company where I work. I just want to delve more deeply into the integration of more sustainable systems and a way in which the knowledge can be transferred to the 'normal' building owner.

4.2 Research output

Deliverables:

1. A heat pump decision tool for homeowners.

5.1 Outline and methodology + data collection and data analysis

This thesis is structured in three consecutive parts. The theoretical framework, empirical research and research by design. This structure of research is necessary because the information gathered in the section leads to a follow-up step in the next section. In (Figure 1) an overview can be found.

Theoretical framework

Theoretical framework chapter 1

Create an overview of the current energy sources used in the built environment and their size for in particular space heating throughout different scales: European, Dutch, building. And get insights about the need for change of the currently most used energy source. Create an overview of possible renewable energy sources contributing to the energy transition throughout the different scales.

Data collection

Overview of the current energy sources (qualitative data) and the possible renewable sources (qualitative data). The size of the energy usage (quantitative). The need for current energy source change (qualitative data) are all collected through literature research and desk research.

Data analysis

The information obtained gives the researcher and reader an idea of the scientific, practical and social scope of the energy issue in the built environment.

Theoretical framework chapter 2

The second part of the theoretical framework is to get an overview of policies which are made in order to support the energy transition of the built environment introduced both the European Union as well as the Dutch government. This chapter examines how the policies play a role in the design of the heat pump decision making tool.

Data collection

The policies will be collected through government documents due to the absence of scientific literature. The influences of different policies on the built environment (qualitative data) supported by numbers (quantitative data) is collected through literature research.

Data analysis

The information obtained gives the researcher and reader an idea of the scientific, practical and regulatory aspects on the energy transition in the built environment.

Theoretical framework chapter 3

Before the heat pump selection tool can be made, existing situations in which heat pumps are used during the renovation of a space heating system must first be examined, so that all additional matters at building envelope level can be investigated and what problems the integration in existing building entails.

Data collection

The renovation cases are selected based on the usage of a heat pump or other low temperature heat source + they are Zero on the Meter the so called NOM renovations. The data is collected through desk research and observation research.

Data analysis

The information obtained gives the researcher and reader an idea of the practical scope of the current application of heat pump systems in the current built environment. This knowledge is necessary in order to develop the heat pump decision tool.

Theoretical framework chapter 4

An overview of potential heat pump systems and sustainable heating sources which can contribute to the energy transition of the built environment and why they will be included in the tool, or why not.

Data collection
Qualitative data is collected through desk research.

Data analysis
The systems and sources are analysed based on disadvantages, advantages, cost-benefits, carbon/energy gains, strategy for integration in built environment, included in the rest of this thesis (high or low contribution to the energy transition of the built environment).

Empirical research

Empirical research chapter 5
The objective of this chapter is to pick the strong usable elements from the different existing tools and combine those plus elements which are missing in the existing tools, to make the heat pump decision tool for home owners in this thesis.

Data collection
Observation study on existing heat pump decision aid tools

Data analysis
The data is analysed looking at strength and weaknesses of existing online tools concerning. And parts which are lacking in existing tools.

Empirical research chapter 6
Get a more in depth knowledge about the integration of the existing heat pump systems and heat emitters and their boundaries.

Data collection
the data is collected through desk research and technical documents about the heat pump systems.

Data analysis
The chosen systems + the technical findings are displayed after each other

Empirical research chapter 7
Using exploratory research and using example cases to make clear how the heat pump tool fulfils an educational function for the benefit of the home user in terms of insulation, costs, indoor comfort and to contribute to the energy transition of the built environment.

Data collection
The data is collected through exploratory research based on heat pump system application and degree of insulation on an example building. And the opinion of other on the field on the degree of insulation in the built environment of existing buildings is collected on the basis of a parliamentary letter.

Data analysis
Causal relations are analysed between extra insulation and indoor comfort. And causal relations are analysed between degree of insulation, system costs, energy consumption, and CO_2 emissions.

Research by design

Research by design chapter 8

Almost all the knowledge to build the tool is known by now and now it's time start building the tool with all the information obtained through research. All the lacking knowledge should be filled in with additional research. The purpose of the tool is to educate the user on the importance of insulating an existing home and to give an advice on what amount of insulation, which heat pump system and which emission system is applicable for the home.

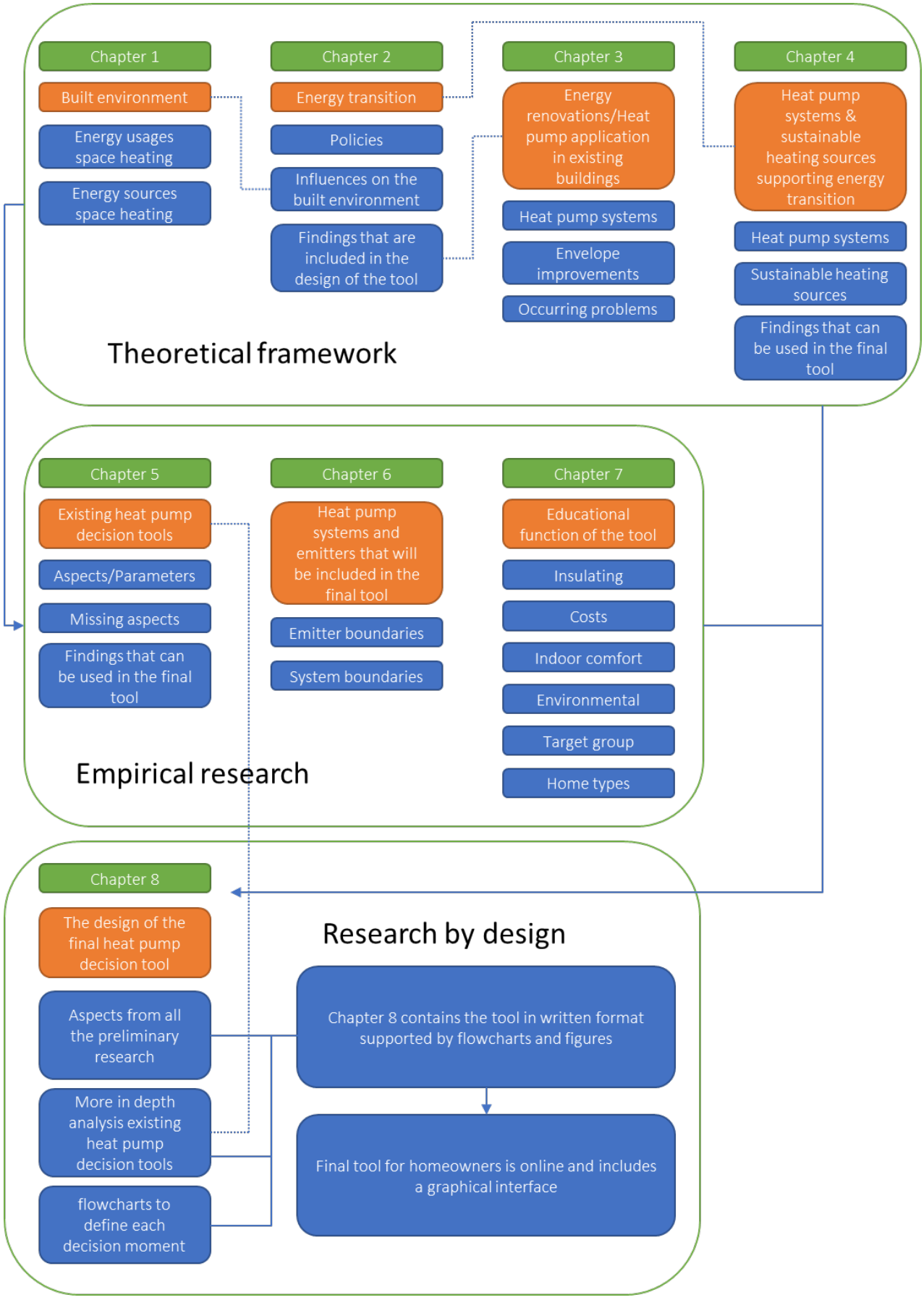

Figure 1. Methodology scheme (Own work)

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