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A B S T R A C T

This paper demonstrates an approach to assess, ex ante, the social acceptance of sustainable heating systems in city districts. More sustainable heating systems are required in city districts to reduce greenhouse gas emissions. However, these systems may lack social acceptance as they often require significant adjustments to homes and may lead to a noticeable loss of in-home thermal comfort. Predicting social acceptance is often difficult due to the long-term planning horizon for energy systems. It is therefore unclear which design requirements and policy guidelines need to be specified ex ante. We suggest an approach to anticipate social acceptance by identifying value conflicts embedded in sustainable heating systems in specific social settings. These value conflicts might cause a lack of social acceptance over time due to value change. We demonstrate this approach using a case of community-driven heating initiative in The Hague, the Netherlands. We identify value conflicts embedded in various sustainable heating systems using an agent-based model. We formulate scenarios of value change to understand the severity of resulting social acceptance issues and discuss suitable heating systems for the city district. The approach can be used to support the decision-making process of policymakers at the local level, even in situations of limited local expertise.

1. Introduction

The deployment and operation of sustainable heating systems for city districts may lack social acceptance. In 2019, the Netherlands had the fifth-highest greenhouse gas emission (GHG) per inhabitant in the European Union (Statistics Netherlands, 2019). Residential heating largely accounts for these high figures, with approximately 10% of Dutch GHG emissions (PBL, 2019). A vast majority of households currently rely on natural gas for residential heating (Gerdes et al., 2016). Multiple sustainable heating systems are available to replace current natural gas heating. These include hydrogen networks (Klip, 2017), combinations of photovoltaics, batteries, and heat pumps in houses (Litjens et al., 2018), and sustainable district heating (Persson and Werner, 2011). However, it is unclear whether these systems are socially acceptable. Most sustainable heating systems may require significant financial efforts from households (Hers et al., 2018) and sacrifices in terms of in-home thermal comfort. It is uncertain whether households in city districts will be willing to commit to such investments and purchase heat above the market price.

The social acceptance of sustainable heating systems in city districts is difficult to assess ex ante but can be addressed by specifying design requirements and policy guidelines to cope with households' concerns. These design requirements and policy guidelines should preferably be specified during the planning phase (i.e. ex ante) (Künneke et al., 2015; Taebi et al., 2014). Later changes, such as replacing parts of the existing physical infrastructure or renegotiating contracts with suppliers and consumers, may result in significant additional costs. However, a potential future lack of social acceptance is difficult to anticipate. Future household decisions to protest or not to support the sustainable heating system are difficult to predict as they result from partial information sets and interactions with social networks (Rai and Robinson, 2015). As a result, there is often a mismatch between the perceived social acceptance during the planning phase and the actual social acceptance during the deployment and operational phases (Hai et al., 2017; Wolsink, 2007a).

This paper introduces an approach to assess, ex ante, the social

Abbreviations: ABM, Agent-based Modelling; GHG, Greenhouse Gas Emissions; ODD + D, Overview, Design Concepts and Details + Decisions.

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acceptance of sustainable heating systems in city districts by addressing value conflicts embedded in heating systems in specific social settings. These value conflicts can be addressed in the planning phase before they materialise into a lack of social acceptance. Our approach consists of two steps. First, we identify value conflicts embedded in sustainable heating systems using an agent-based model (Epstein and Axtell, 1996). Such a model is well suited to simulate the effects of heterogeneous characteristics of households and housing on emergent system features (i.e. value conflicts) (Rahmandad and Sterman, 2008). Second, we evaluate the impact of identified value conflicts on social acceptance by identifying scenarios of value change (van de Poel, 2018). Value change could lead to a mismatch between values prioritised in sustainable heating systems and those prioritised in society. This mismatch may result in a lack of social acceptance. Our research question is the following: *How can we assess* ex ante *the social acceptance of household sustainable heating systems at the city district level by addressing value conflicts?*

This paper is structured as follows. Section 2 describes the challenges of assessing the social acceptance of sustainable heating systems for city districts. In Section 3, we suggest an approach to anticipate social acceptance by addressing value conflicts embedded in sustainable heating systems. In Section 4, we describe the methods, the case, and the model used to identify value conflicts in sustainable heating systems. Section 5 presents model results and evaluates which sustainable heating systems would be more suitable with regard to social acceptance. Conclusions, policy implications, and suggestions for future research are discussed in Section 6.

2. Theory: sustainable heating systems and social acceptance

In the Netherlands, there are multiple sustainable heating systems that can replace residential natural gas heating. These systems rely on renewable energy sources or waste heat. Renewable sources include renewable gas (Jensen et al., 2020), solar collectors (Perez-Mora et al., 2018), geothermal heat (Self et al., 2013), and green electricity (Poppi et al., 2018). Combinations of sources are often used to ensure a better match between heat supply and demand (e.g. Emmi et al. (2017); Khalid et al. (2016); Litjens et al. (2018)). Waste heat can be extracted from industries using high temperature processes and producing large energy soutputs, such as electricity power plants and waste incinerators (Klinghoffer and Castaldi, 2013; Sarkar and Bhattacharyya, 2012; Werner, 2017). Sustainable heating systems can be implemented at various levels. At the national level, hydrogen produced using renewable electricity could replace natural gas supply (Kampman, 2019; Meibom and Karlsson, 2010). At the city level, district heating systems can be built. Such systems (re-)use local heat resources to serve local heating demand (Werner, 2017). At the household level, households can complement existing heat supply with residential heat pumps (Petrović and Karlsson, 2016). Depending on the level of implementation, ownership and control may vary among private and public companies, public organisations, individual households, and community co-operatives and collectives (Warbroek et al., 2019; Zeman and Werner, 2004).

Multiple challenges exist in replacing residential natural gas heating with more sustainable systems. At the technical level, the current heating infrastructure may require considerable adjustments (Li et al., 2017; Lund et al., 2014; Werner, 2017). At the regulatory level, existing regulations regarding heat trading and pricing often need to be adjusted to accommodate new governance models (Schilling et al., 2017; Warbroek et al., 2019). At the financial level, arrangements are needed to cope with the typically high sunk costs of new heating infrastructures (Blom, 2017). An additional challenge is the potential lack of social acceptance of sustainable heating systems by households.

Social acceptance conveys both the more passive notion of accepting the technology (i.e. not resisting its deployment) and the more active notion in terms of support and adoption of technologies (Batel et al., 2013). Sustainable heating systems may have significant drawbacks for households, which may result in a lack of social acceptance. In the Netherlands, the replacement of natural gas heating by CO_2 neutral systems will add on average €1000 of heating costs per household per year (Hers et al., 2018). Sustainable heating systems may change levels of in-home thermal comfort (insufficient radiant heat and humidity issues), mostly for households living in older houses (Hernández, 2015). Social tensions may arise, for example between households having access to lower heating costs and others without this access (Hers et al., 2018). Due to these drawbacks, households may decide not to purchase or not to use the required heating appliances (Sauter and Watson, 2007; Sovacool et al., 2019). They may also decide to compensate for the loss of thermal comfort in a non-sustainable manner (Aydin et al., 2017; Hong et al., 2006; Seebauer, 2018). Ultimately, overall heating costs may increase, and issues of energy poverty may appear (Hast et al., 2018; Reames, 2016).

The potential lack of social acceptance of sustainable heating systems can be addressed by specifying design requirements and policy guidelines ex ante. For example, subsidies can be provided to make heating appliances more affordable (Hers et al., 2018). Heating systems can be chosen that offer a better balance between environmental sustainability and in-home thermal comfort in city districts with poorly thermally insulated houses. Specifying design requirements and policy guidelines to support social acceptance requires anticipating future households' decisions not to accept sustainable heating systems. This information can be used to adjust the system adequately.

The difficulty is that households' decisions not to accept sustainable heating systems are highly uncertain and difficult to predict. We identify two reasons why social acceptance is difficult to predict. First, it is often difficult to assess the exact impact of sustainable heating systems on households. The suitability of these systems is dependent on the "geographical assemblage of networked materialities and socioeconomic relations" (Harrison and Popke, 2011) that characterises city districts. Effective technical solutions depend on local characteristics in terms of housing, geographic location, and existing infrastructure (Millar et al., 2019; Reames, 2016; Schilling et al., 2019; Werner, 2017). Second, even if project developers were to know the exact impact of sustainable heating systems, the perception of these impacts by households, and therefore their acceptance is often highly unpredictable. Household perception depends on a range of intertwined factors. These include psychological factors such as awareness, motivation, knowledge, and social networks (Huijts et al., 2012; Niamir et al., 2018; Rai and Robinson, 2015; Stigka et al., 2014). Perception might change over time as households learn from using the heating system (Niamir et al., 2018) and due to other exogenous societal changes (e.g. economic, social, and technological developments).

The difficulty of anticipating social acceptance means that there is often a discrepancy between the perceived social acceptance during the planning phase and the revealed social acceptance during the deployment and operation phases of energy systems (Eltham et al., 2008; Wolsink, 2007b). As a result, specified design requirements and policy guidelines to support social acceptance are not effective.

3. Proposed approach

In this section, we propose an alternative approach to anticipate the social acceptance of sustainable heating systems. The approach entails identifying value conflicts embedded in heating systems in specific social settings (i.e. risks or a future lack of social acceptance) and understanding which scenarios of value change could result in a lack of social acceptance.

Designing regulatory and technological systems often requires coping with value conflicts. Values can be defined as "lasting convictions or matters that people feel should be strived for in general and not just for themselves to be able to lead a good life or realise a good society" (van de Poel and Royakkers, 2011). Examples of values are *privacy*, *autonomy* (Friedman et al., 2006), and *security* (Schwartz, 2012).

Technologies are 'value-laden' (Verbeek, 2011; Winner, 1980): they are often designed to achieve certain values, but the realisation of these values often jeopardise the realisation of others. For example, the smart meter was deployed to achieve *reliability* in electricity supply (Jackson, 2014). However, *reliability* is supported by using household consumption data, which means this value is in conflict with the value *privacy*. Another example of a value conflict in energy systems is *environmental sustainability* versus *landscape authenticity* in the deployment of industrial wind farms (Söderholm and Pettersson, 2011) where the general public is prioritised over local communities (Wüstenhagen et al., 2007).

The fact that regulatory and technological systems embed value conflicts means that they are prone to a lack of social acceptance. When two values are in conflict for the realisation of a system, its deployment inherently requires balancing the values, which often means favouring one value over the other (for example, *reliability* was favoured over *privacy* in the case of the smart meter). At different moments during the planning, deployment, and operation phase of these systems, societal groups that feel negatively affected by disfavoured values may take action in defence of their values. This includes public protests, political movements, or a lack of adoption of technologies. During the planning phase, local communities may, for example, voice their concerns during public consultation procedures (Wolsink, 2007a). During the deployment and operational phase, consumers may refuse to invest in or use appliances on which the system depends (Sauter and Watson, 2007).

The consequences of value conflicts on a future lack of social acceptance can be anticipated by identifying scenarios of value change. Value change refers to changing prioritisations among values over time (van de Poel, 2018). While the deployment of the system inherently crystallises a prioritisation between two conflicting values, the societal desired prioritisation of values may change over time. An example is *environmental sustainability* versus *affordability* in the current energy transition (Rösch et al., 2017; Shortall and Davidsdottir, 2017). Although consumers may initially have agreed to pay higher heating prices (*affordability*) to support sustainable initiatives (*environmental sustainability*), preferences could change as a result of an economic recession. An economic recession is an example of a scenario of value change that could result in a lack of social acceptance. Others include technological innovations and political movements. The occurrence of such scenarios of value change may endanger the financial viability of sustainable heating systems.

The proposed approach is different than a typical one which aims to predict households' decisions (see Section 2). Factors related to household decision-making (e.g. attitudes, intentions, availability of information) are not included in our analysis. Rather, we assess conflicting opportunities for households to realise their values. More affluent households, for example, could choose to invest in sustainable heating systems and become more *environmentally sustainable*, but this decision might affect the *inclusiveness* of the less affluent ones. Factors affecting these opportunities are the socioeconomic and housing characteristics of households (i.e. their living conditions).

Although addressing value conflicts might not allow us to exactly predict future acceptance (which is challenging in the case of sustainable heating systems in any approach), it can help to identify potential risks and understand when these risks can become problematic. This information will help to further specify design requirements and policy guidelines ex ante in support of future social acceptance.

4. Methods, case, and model description

This section presents the methods, the case, and the model used to identify value conflicts embedded in sustainable heating systems for city districts. Section 4.1 presents the two methods used to identify value conflicts embedded in heating systems: agent-based modelling and the scenario discovery technique. Section 4.2 introduces the community-driven heating initiative in 'de Vruchtenbuurt' which is used as a case. Section 4.3 explains the model conceptualisation and Section 4.4 describes the model specification.

4.1. Methods

We use agent-based modelling and the scenario discovery technique to identify value conflicts in sustainable heating systems for city districts. We introduce both methods in Section 4.1.1 and Section 4.1.2 respectively and argue why they were selected given the research objective.

4.1.1. Agent-based modelling (ABM)

ABM is a simulation technique originating from the field of complexity science (Bankes et al., 2002). It is used to capture emergent phenomena in social systems (Bonabeau, 2002). In an ABM, entities that are part of the social system (e.g. individuals, households) are modelled as a set of heterogeneous and autonomous software agents who pursue predefined individual goals by performing a set of actions. The fact that agents are interdependent in the achievement of their goals means that they act and react to each other. The sequence of actions performed by agents can lead to an emergent system behaviour that is not explicitly engraved in the conceptualisation of the model.

We use ABM to identify value conflicts embedded in heating systems in specific social settings. Multiple techniques exist to simulate the behaviour of social systems. These include computable general equilibrium (Jones, 1965), system dynamics (Forrester, 1958), discrete event simulation (Gordon, 1981), and agent-based modelling (Epstein and Axtell, 1996). ABM is a suitable technique to identify value conflicts because they are emergent phenomena that result from the heterogeneous characteristics and interactions between households. For example, a conflict between the values *environmental sustainability* and *inclusiveness* occurs when there is a group of households that can afford the sustainable heating system and can become more sustainable, and a group that cannot (heterogeneity). This conflict occurs as a result of actions from some households (e.g. the decision to opt for sustainable heating systems), which in turn affects other households (interactions).

4.1.2. The scenario discovery technique

Different sustainable heating systems may embed various value conflicts. For example, some sustainable heating systems may be more affordable, and therefore there is no conflict between *affordability* and *environmental sustainability*. These systems might be more suitable in poorer city districts. Other designs might be less *affordable* but perform better in terms of *environmental sustainability*. These systems could be suitable in wealthier city districts. By comparing sustainable heating systems based on their embedded value conflicts, we can evaluate which systems are suitable for a specific city district in terms of social acceptance.

The scenario discovery technique is useful in combination with the agent-based model to systematically classify which value conflicts are embedded in sustainable heating systems. The scenario discovery technique (Bryant and Lempert, 2010) is an application of Exploratory Modelling and Analysis (Bankes, 1993) and is instrumental in classifying value conflicts that are embedded in sustainable heating systems. It can systematically classify which combination of model input parameters (scenarios) in a series of model runs leads to a particular outcome (Kwakkel and Pruyt, 2013). In our work, combinations of model input parameters are sustainable heating systems. The outcomes of interest are the value conflicts that the agent-based model can find.

4.2. Introduction to the community driven heating initiative in 'de Vruchtenbuurt'

We demonstrate the approach to assess, ex ante, the social acceptance of heating systems by using a case of community driven heating initiative in a city district named 'de Vruchtenbuurt' (in English 'the fruit neighbourhood') in The Hague, the Netherlands. The use of a case is needed because the occurrence of value conflicts in city districts is not generic but results from the characteristics in terms of households and housing (de Wildt et al., 2020).

In 'de Vruchtenbuurt', most houses are currently heated by natural gas from the national grid. In 2015, a group of citizens created an initiative named 'Warm in de Wijk' (Coöperatie Duurzame Vruchtenbuurt U.A., 2017) to find and deploy a more sustainable system than natural gas heating. The citizens' initiative is considering multiple sustainable heating systems, which are described in Section 4.4.2. It is however unclear which systems are more suitable given the characteristics of the city district in terms of households and housing.

We choose this case for two reasons. First, there is a societal need for research since members of the heating initiative are currently discussing different heating systems. Long-term commitment from participating households is essential but can be uncertain over time. Second, the case is typical for many city districts in the Netherlands in terms of city district characteristics and feasible heating systems. Most houses were built after 1945 (IF Technology, 2018), are not or poorly thermally insulated (EnergieAtlas, 2019), and 80.2% of households are home-owners (The Hague, 2019).

4.3. Model conceptualisation

In this work, we use the agent-based model to identify capability conflicts published by de Wildt et al. (2020). We extend and refine the model to identify value conflicts in a spatially explicit model with realistic (non-random) heterogenous households. This newly created agent-based model visualises 'de Vruchtenbuurt' and its households. The households are modelled as 'agents'. They have characteristics including annual disposable income, heat consumption, type of household, energy label, and housing surface area.

To identify embedded value conflicts, households in the model make choices to satisfy their values.[1] These choices are: (1) use (or continue to use) the sustainable heating option evaluated in the model or (2) use (or continue to use) traditional natural gas heating. For example, choosing traditional natural gas heating might be more beneficial in terms of *affordability*. This might not be the case for all households. The realisation of some values may conflict with other values. An example is provided in Fig. 1. To realise *environmental sustainability*, household A1 might decide to switch from natural gas to sustainable heating. This decision might lead to a loss in-home *thermal comfort* if the house is poorly insulated. Hence, *environmental sustainability* and *thermal comfort* are in conflict for this household. Moreover, the realisation of *environmental sustainability* by household A1 may affect household A2. Household A2 might not have sufficient income to switch to sustainable heating. If most of A2's neighbours switch to sustainable heating, household A2's *inclusiveness* could decrease. The realisation of *environmental sustainability* by household A1 is therefore in conflict with the realisation of *inclusiveness* by household A2.

The model runs until an equilibrium is reached. This means that no agents can further increase the fulfilment of their values. At the end of the model run, we identify whether a particular value increases or decreases for each agent.

The model was implemented in Netlogo (Wilensky, 1999) and is available using the following link *(link will be disclosed after review)*. The full model description can be found in Appendix E, following the ODD + D (Overview, Design Concepts and Details + Decision) protocol (Müller et al., 2013). We use the 'evaludation method' of Augusiak et al. (2014) to verify and validate the model. The scenario discovery experiment is performed using PyNetLogo (Jaxa-Rozen and Kwakkel, 2018). Section 4.4. describes the model specifications.

[1] This is a way to identify value conflicts in the agent-based model. We do not claim that this is what households actually do.

4.4. Model specification

The data collected for the case introduced in Section 4.2 consist of (1) values and their conceptualisation for 'de Vruchtenbuurt', (2) the sustainable heating systems considered by the community-driven heating initiative, and (3) the housing and household data in 'de Vruchtenbuurt'. In this section, we present this data and explain how it was collected.

4.4.1. Values

Relevant values and their conceptualisation for the city district can be identified through expert interviews or household surveys. We used expert interviews because values and their conceptualisation follow from the characteristics of the various heating options and their possible negative impacts now and in the future. Experts typically have a clearer understanding of these systems and their potential societal risks. Households may have more limited knowledge of these systems and only perceive the risks when they actually face specific negative impacts. Expert knowledge may still be limited with regard to the diversity of households and houses. We reflect on the limitations of our choice to perform expert interviews in Section 6.1 and suggest the use of participatory approaches for future cases in Section 6.4.

Appendix A gives a detailed overview of our interviewees. We interviewed experts from a range of organisations: the Ministry of Economic Affairs and Climate Policy of the Netherlands, the Municipality of The Hague, The Netherlands Enterprise Agency, The Netherlands Organisation for Applied Scientific Research (TNO), Stedin, the local distribution network operator, and 'Warm in de Wijk', a citizens' initiative. These interviews provided a complete overview of the suitability of the heating systems, the social aspects related to their deployment and utilisation, and the specific characteristics of 'de Vruchtenbuurt' in terms of households and housing.

Interviews were conducted in two rounds. First, we made a list of values based on five articles addressing values in the energy sector (Demski et al., 2015; Künneke et al., 2015; Ligtvoet et al., 2015; Milchram et al, 2018, 2019). We discussed this list with the interviewees and asked them to select the values they thought should be taken into account when switching to a new heating system in 'de Vruchtenbuurt'. We also asked them which characteristics of households and housing could influence the realisation of these values considering the specific characteristics of the heating systems. The first round resulted in a list of relevant values for 'de Vruchtenbuurt' with a definition for each value and a corresponding empirical conceptualisation. These were verified in a second round with four policymakers specialised in energy at the ministerial level and one local initiator of the project in 'de Vruchtenbuurt'. Appendix B includes a list of interview questions.

We identified the following five values: *thermal comfort*, *affordability*, *environmental sustainability*, *autonomy*, and *inclusiveness* (see Table 1). The conceptualisation of these values can be found in the ODD + D (Müller et al., 2013) model description in Appendix E.

4.4.2. Sustainable heating systems

The sustainable heating systems considered were obtained by consulting documents shared by the 'Duurzame Vruchtenbuurt U.A.' cooperative, the initiators of the project. Further technical data (e.g. efficiency of various technologies) and financial data for these systems and thermal insulation were taken from a range of reports from research institutions (Appendix D).

Table 2 lists the sustainable heating systems considered by the initiative. These systems were developed by the citizens' initiative and an engineering company named IF Technology. The first type is a 70 °C district heating system. Possible heat sources are waste heat from industries located in the port of Rotterdam or collective thermal heat (55 °C heat) from a geothermal plant and a collective heat pump. However, this would mean installing a new heat network in the district. A heat exchanger would replace gas boilers in households. Improved housing thermal insulation is not strictly required but advised to

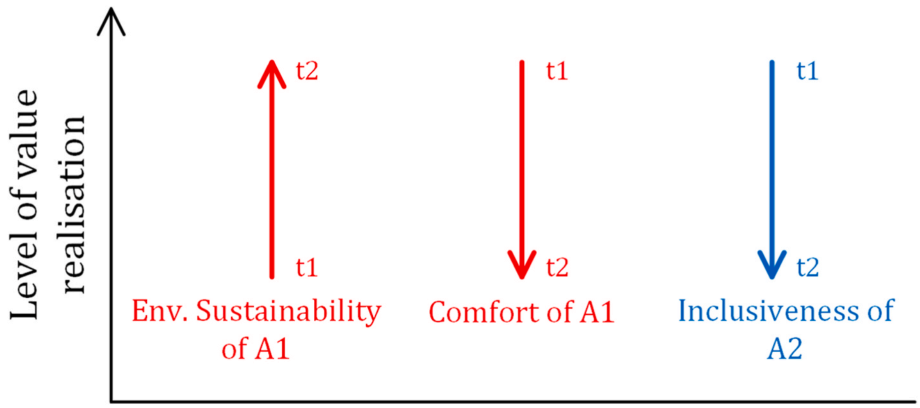

Fig. 1. Example of value conflicts created as a result of switching to sustainable heating by household A1 on itself and on household A2.

Table 1
Values identified for 'de Vruchtenbuurt' case.

Values	Definition
Thermal Comfort	The extent to which households receive the appropriate heating level to ensure sufficient well-being.
Affordability	The extent to which households spend a reasonable amount of their disposable income on the heating and the purchase of heating related appliances.
Environmental Sustainability	The extent to which households have a limited impact on the ecosystem.
Autonomy	The extent to which households can choose their preferred heating consumption.
Inclusiveness	The extent to which households can engage in shared activities.

maintain similar levels of thermal comfort. The second type, a 40 °C district heating system, is similar and could use the same geothermal plant. However, this would require significant adjustments to homes. Individual heat pumps or electric boilers would be needed to top up the heat to 60 °C. Standard radiators would have to be replaced by low-temperature ones or by floor heating. Houses would have to be thermally insulated (i.e. floor, roof, HR++ windows). The third type, the all-electric system, leaves more room for individual preferences: heat pumps, electric boilers, or a combination of heat sources. However, it would also require major adjustments to homes, similar to those mentioned above.

4.4.3. Household and housing data

The characteristics of households and housing influence the suitability of heating systems. Housing data include the energy label, and the type and square meter surface of the housing. We collected energy labels from the Dutch National Energy Atlas website (EnergieAtlas, 2019). We identified three types of housing (single-family houses, duplexes, and flats) using Google Maps. The surface of houses was taken from a feasibility study for city district heating made by IF Technology (2018).

Household data includes annual disposable income, the type of household, the type of electricity consumed (green or grey), the type of ownership, and heat consumption. This data is only available at the city district and city level on the statistics website 'Den Haag in Cijfers' (The Hague, 2019), Statistics Netherlands (CBS, 2019), and the Dutch Authority for Consumers & Markets (ACM, 2017). We distributed this data over individual households by using correlations between these attributes in the literature (MBZK, 2019). In case no correlations were found, we distributed the data randomly. Using the scenario discovery technique (see Section 4.1.2), we ran the model multiple times to compensate for this randomness.

Appendix C provides a detailed overview of household and housing data, including the sources of these data. Appendix E gives an overview of how these data relate to the realisation of values by households in the ODD + D model.

5. Results

5.1. Value conflicts embedded in sustainable heating systems

Table 3 gives an overview of the identified value conflicts embedded in the heating systems. The columns show the system types and

Table 2
Sustainable heating systems considered in 'de Vruchtenbuurt', The Hague.

Type of heating system	Subtype	Central/common heat source	Heat transport	Individual heat source	Additional house adjustments
70°C district heating system	1.1	Waste heat	New heat network		Heat exchanger Thermal insulation to energy label C
	1.2	Collective geothermal heat	New heat network	Collective heat pumps	Heat exchanger Thermal insulation to energy label C
40°C district heating system	2.1	Collective geothermal heat	New heat network	Individual heat pumps	Heat exchanger Replacement of radiators or floor heating Thermal insulation to energy label A
	2.2	Collective geothermal heat	New heat network	Electric boilers	Heat exchanger Thermal insulation to energy label A
All-electric heating system	3.1			Individual heat pumps	Replacement of radiators or floor heating Thermal insulation to energy label A
	3.2			Electric boilers	Thermal insulation to energy label A
	3.3			Individual heat pumps and electric boilers	Thermal insulation to energy label C

Table 3
Overview of value conflicts per system type and subtype (abbreviations are described in the legend).

Sustainable heating systems	**70°C district heating**																	
Subtype	***1.1***									***1.2***								
Heat source 1	**Waste heat**									**Collective goethermal heat**								
Ownership	External party									External party								
Financial support	N									N								
Heat source 2										**Collective heat pumps**								
Ownership										Cooperative								
Financial support										S	S	S	L	L	L	N	N	N
Required changes in houses	**Heat exchanger**									**Heat exchanger**								
Financial support	S	S	S	L	L	L	N	N	N	S	S	S	L	L	L	N	N	N
Advised thermal insulation	**Energy label C**									**Energy label C**								
Financial support	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N
Thermal Comfort vs. Thermal Comfort	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermal Comfort vs. Affordability	0.3	0	0.8	0.2	0	0.8	0.5	0	0.8	0.3	0.1	0.4	0.4	0.1	0.6	0.3	0.2	0.4
Thermal Comfort vs. Env. Sustainability	0	0	0	0	0	0	0	0	0	0.3	0.1	0.4	0.4	0.1	0.6	0.3	0.2	0.4
Thermal Comfort vs. Autonomy	0.1	0.1	0.3	0.3	0.1	0.2	0.3	0.2	0.1	0	0	0	0	0	0	0	0	0
Thermal Comfort vs. Inclusiveness	1	0.9	0.9	1	1	0.9	0.9	0.9	0.9	0.3	0.1	0.4	0.3	0.1	0.6	0.3	0.1	0.4
Affordability vs. Affordability	0.3	0	0.8	0.2	0	0.8	0.5	0	0.8	0.4	0.1	0.7	0.2	0.1	0.7	0.5	0.1	0.6
Affordability vs. Env. Sustainability	0.3	0	0.8	0.2	0	0.8	0.5	0	0.9	0.4	0.1	0.8	0.3	0.1	0.7	0.6	0.3	0.8
Affordability vs. Autonomy	0.1	0.1	0.3	0.3	0.1	0.2	0.3	0.3	0.2	0.1	0.3	0.2	0.1	0.1	0.3	0.2	0.1	0.1
Affordability vs. Inclusiveness	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Env. Sustainability vs. Env. Sustainability	0	0	0	0	0	0	0	0	0	0.1	0	0.1	0	0	0	0.1	0.1	0.2
Env. Sustainability vs. Autonomy	0.1	0.1	0.3	0.3	0.1	0.2	0.3	0.3	0.2	0.1	0.3	0.2	0.1	0.1	0.3	0.2	0.1	0.1
Env. Sustainability vs. Inclusiveness	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Autonomy vs. Autonomy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Autonomy vs. Inclusiveness	0.1	0.1	0.3	0.3	0.1	0.2	0.3	0.3	0.2	0.1	0.3	0.2	0.1	0.1	0.3	0.2	0.1	0.1
Inclusiveness vs. Inclusiveness	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Sustainable heating systems	**40°C district heating**																	
Subtype	***2.1***									***2.2***								
Heat source 1	**Collective goethermal heat**									**Collective goethermal heat**								
Ownership	External party									External party								
Financial support	N									N								
Heat source 2	**Individual heat pumps**									**Electric boiler**								
Ownership	Individual households									Individual households								
Financial support	S	S	S	L	L	L	N	N	N	S	S	S	L	L	L	N	N	N
Required changes in houses	**Heat exch. + rad. + fl. heating**									**Heat exchanger**								
Financial support	S	S	S	L	L	L	N	N	N	S	S	S	L	L	L	N	N	N
Advised thermal insulation	**Energy label A**									**Energy label A**								
Financial support	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N
Thermal Comfort vs. Thermal Comfort	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermal Comfort vs. Affordability	0.1	0	0.2	0.1	0	0.3	0	0	0.1	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.5	0.3
Thermal Comfort vs. Env. Sustainability	0.1	0	0.4	0.2	0	0.4	0.1	0	0.2	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0
Thermal Comfort vs. Autonomy	0.1	0	0	0	0	0.1	0	0	0	0.2	0.1	0.2	0.2	0.3	0.2	0.1	0.1	0.1
Thermal Comfort vs. Inclusiveness	0.1	0	0.3	0.1	0	0.4	0.1	0	0.2	0.5	0.7	0.4	0.6	0.7	0.4	0.5	0.6	0.3
Affordability vs. Affordability	0.3	0.5	0.1	0.4	0.1	0.1	0.2	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Affordability vs. Env. Sustainability	0.6	0.6	0.8	0.6	0.2	0.9	0.8	0.8	0.9	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.9	0.8
Affordability vs. Autonomy	0.2	0.3	0.1	0.1	0.3	0.1	0.1	0.2	0.1	0.2	0	0.1	0.2	0.2	0.2	0.2	0.1	0.2
Affordability vs. Inclusiveness	0.9	1	0.9	1	0.9	1	0.8	0.9	0.9	0.6	0.7	0.5	0.7	0.8	0.6	0.6	0.7	0.5
Env. Sustainability vs. Env. Sustainability	0.2	0.1	0.3	0.1	0.1	0.2	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Env. Sustainability vs. Autonomy	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.4	0.3	0.1	0.2	0.3	0.4	0.3	0.2	0.1	0.2
Env. Sustainability vs. Inclusiveness	1	1	1	1	1	1	0.9	1	0.9	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.9	0.8
Autonomy vs. Autonomy	0.1	0.1	0	0	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1	0	0.2
Autonomy vs. Inclusiveness	0.4	0.3	0.2	0.2	0.4	0.3	0.2	0.2	0.4	0.3	0.1	0.2	0.3	0.4	0.3	0.3	0.2	0.2
Inclusiveness vs. Inclusiveness	1	1	0.9	1	1	0.9	0.9	0.9	0.9	0.6	0.7	0.5	0.7	0.8	0.6	0.6	0.7	0.5

Sustainable heating systems	**All electric**																										
Subtype	***3.1***									***3.2***									***3.3***								
Heat source 1	**Individual heat pump**									**Electric boiler**									**Individual heat pump**								
Ownership	Individual households									Individual households									Individual households								
Financial support	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N	S	L	N
Heat source 2																			**Electric boiler**								
Ownership																			Individual households								
Financial support																			S	L	N	S	L	N	S	L	N
Required changes in houses	**Radiators + floor heating**																										
Financial support	S	L	N	S	L	N	S	L	N																		
Advised thermal insulation	**Energy label A**									**Energy label A**									**Energy label C**								
Financial support	S	L	N	N	S	L	L	N	S	S	L	N	N	S	L	L	N	S	S	L	N	N	S	L	L	N	S
Thermal Comfort vs. Thermal Comfort	0.2	0.2	0.1	0.1	0.3	0.2	0.2	0.1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermal Comfort vs. Affordability	0.2	0.2	0.1	0.1	0.3	0.2	0.2	0.1	0.3	0	0.1	0	0	0	0.1	0	0	0	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.2
Thermal Comfort vs. Env. Sustainability	0.8	0.9	0.8	0.7	0.9	0.8	0.9	0.8	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermal Comfort vs. Autonomy	0.3	0.2	0.1	0.3	0.3	0.2	0.2	0.3	0.3	0	0	0	0	0	0	0	0	0	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1
Thermal Comfort vs. Inclusiveness	0.5	0.4	0.3	0.3	0.6	0.4	0.5	0.3	0.4	0	0.1	0	0	0	0.1	0	0	0	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.2
Affordability vs. Affordability	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Affordability vs. Env. Sustainability	0.8	0.9	0.8	0.7	0.9	0.8	0.9	0.8	0.8	0.5	0.7	0.6	0.6	0.5	0.7	0.5	0.6	0.6	0.8	0.8	0.6	0.8	0.8	0.7	0.8	0.7	0.7
Affordability vs. Autonomy	0.3	0.2	0.1	0.2	0.3	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.3	0.1	0.2	0.3	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.1	0.1
Affordability vs. Inclusiveness	0.5	0.4	0.3	0.3	0.6	0.4	0.4	0.3	0.4	0.1	0.3	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.4	0.5	0.4	0.4	0.5	0.5	0.4	0.4	0.4
Env. Sustainability vs. Env. Sustainability	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Env. Sustainability vs. Autonomy	0.3	0.3	0.1	0.2	0.4	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.1	0.2	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.1	0.4	0.3	0.1	0.2
Env. Sustainability vs. Inclusiveness	0.8	0.9	0.8	0.7	0.9	0.8	0.9	0.8	0.8	0.5	0.7	0.6	0.6	0.5	0.7	0.5	0.6	0.6	0.8	0.8	0.6	0.8	0.8	0.7	0.8	0.7	0.7
Autonomy vs. Autonomy	0.1	0.1	0	0.1	0.2	0	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Autonomy vs. Inclusiveness	0.4	0.3	0.1	0.3	0.5	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.1	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.4	0.4	0.2	0.2
Inclusiveness vs. Inclusiveness	0.5	0.4	0.3	0.3	0.6	0.4	0.4	0.3	0.4	0.1	0.3	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.4	0.5	0.4	0.4	0.5	0.5	0.4	0.4	0.4

Legend
Financial support

S = Subsidy
L = Zero percent loan
N = No support

Frequency of conflicts

0 Conflict found in 0% of model runs
0.5 Conflict found in 50% of model runs
1 Conflict found in 100% of model runs

subtypes, and the rows show all combinations between two values. We test different funding options for each type of system on their ability to resolve value conflicts. We test two common financial instruments for energy efficiency measures (zero-interest loans (L) and subsidies (S)). These two financial instruments were selected because they are commonly used to support the adoption of energy-efficient technologies (Hesselink and Chappin, 2019). Systems without financial support are also tested (no support (N)). The data and colours at the intersections between heating systems and the combination of two values are indicators of whether these values conflict. For each type of system, the model was run multiple times due to stochastic uncertainty resulting from the order of actions between agents (see Briggs et al. (2012)). A '0' (green) means that the combination of two values was never found to be in conflict in any of the model runs made in the scenario discovery experiment. '0.7' (orange) means that the combination of two values was found to be in conflict in 70% of model runs. In this section, we discuss value conflicts identified per system type. Due to their high number, we combined value conflicts in groups if they affected the same types of households.

5.1.1. 70 °C district heating systems

5.1.1.1. *Group 1 conflicts: Environmental Sustainability and Autonomy vs. Thermal Comfort (with an increase in thermal comfort for some households).*

This group of value conflicts is embedded in the 70 °C district heating system. It occurs in geothermal systems combined with heat pumps (1.2). Households can become more *environmentally sustainable* and *autonomous* by choosing this system, but their *thermal comfort* might decrease due to the use of heat pumps. The maximum temperature that can be generated is limited if these pumps are not combined with a high-temperature heat source (e.g. an electric boiler). This would affect the lowest income households and those living in houses with low energy labels who may not be able to afford thermal insulation (see Table 4).

Table 4
Environmental Sustainability and Autonomy vs. Thermal Comfort.

Values in conflict	Households positively affected	Households negatively affected
Environmental Sustainability Autonomy	- Middle and high income - Middle and high demand - Living in single-family houses and duplexes	
vs.		
Thermal Comfort	- High income - Middle and high heat demand - Living in single-family houses	- Low and middle income - Low energy labels - Living in duplexes and flats - Often poorer households located close to richer households

5.1.1.2. Group 2 conflicts: Environmental Sustainability and Autonomy vs. Affordability (with an increase in affordability for some households). This group of value conflicts occurs in the 70 °C district heating system, both with waste heat (1.1) and in geothermal systems combined with collective heat pumps (1.2). A*ffordability* may decrease for lower-income households switching to these systems (see Table 5) as adjustments to housing (changes to the heating system and thermal insulation) may not be affordable. *Affordability* also decreases in households with low heat consumption, such as single-person households but increases in high-income households and those with high heat demand (couples with children and those living in houses). For these households, new heating systems can substantially reduce heat consumption and thus energy costs.

5.1.1.3. Group 3 conflicts: Thermal Comfort vs. Affordability (with an increase in affordability for some households). This group of value conflicts exists in the 70 °C district heating system, specifically in geothermal systems combined with heat pumps (1.2). Switching to this type of heating improves thermal insulation, making houses more comfortable. However, these systems may be expensive. *Affordability* decreases for low-income households with low heat demand (see Table 6).

5.1.1.4. Group 4 conflicts: Environmental Sustainability and Affordability vs. Inclusiveness (inclusiveness issues for lower-income households). This group of value conflicts occurs in the 70 °C district heating system, both in systems with waste heat (1.1) and in geothermal systems combined with collective heat pumps (1.2), and may create *inclusiveness* issues. Lower-income households may not be able to afford all the required appliances and thermal insulation. This is also the case for tenants who are dependent on landlords and housing corporations to change their heating systems.

Fig. 2 shows where issues of *inclusiveness* are concentrated in the 70 °C district heating system. These occur in areas in the city district where some households switched to sustainable heating systems, whereas others, especially those with lower-incomes, still rely on natural gas heating due to either *affordability* issues or because they are tenants (see Table 7).

Table 5
Environmental Sustainability and Autonomy vs. Affordability.

Values in conflict	Households positively affected	Households negatively affected
Environmental Sustainability Autonomy	- Middle and high income - Middle and high demand - Living in single-family houses and duplexes	
vs.		
Affordability	- Middle and high income - High heat demand - Couples with children - Living in single-family houses	- Low and middle income - Low heat demand - Low energy label - Single-person households

Table 6
Thermal Comfort vs. Affordability.

Values in conflict	Households positively affected	Households negatively affected
Thermal Comfort	- High heat demand - Low energy label	
vs.		
Affordability	- High income - Living in single-family houses - Couples with children	- Low income - Low heat demand

5.1.2. 40 °C district heating systems

All groups of value conflicts found in the 70 °C district heating system were also found in the 40 °C district heating system. We identified a value conflict between *environmental sustainability* and *autonomy* versus *thermal comfort* (Group 1) in 2.1, due to the use of individual heat pumps. However, in these heating systems, the loss of *thermal comfort* is even greater than in the 70 °C district heating systems. The value conflict between *environmental sustainability* and *autonomy* versus *affordability* (Group 2) also occurs in 2.1. Some households are negatively affected in terms of *affordability*, whereas others are positively affected. We also identified a value conflict between *thermal comfort* and *affordability* (Group 3). While *thermal comfort* may increase, heat *affordability* tends to decrease for lower-income households with low heat demand. We identified a value conflict between *environmental sustainability* and *autonomy* versus *inclusiveness* (Group 4). *Inclusiveness* issues are similar to those in the 70 °C district heating system. An additional value conflict was found between *environmental sustainability* and *autonomy* versus *affordability* for the option with electric boilers (2.2) where households were affected differently.

5.1.2.1. Group 5 conflicts: Environmental Sustainability and Autonomy vs. Affordability (no increase in affordability). This group of value conflicts is embedded in 40 °C district heating systems. While in Group 2 conflicts, some households have gains in terms of *affordability*, this is not the case here. Heating costs are higher due to the use of electric boilers. Hence, only high-income households, typically those living in single houses, tend to choose 40 °C district heating systems (see Table 8). Although their *thermal comfort* increases due to better home thermal insulation, *affordability* decreases. Zero-interest loans and subsidies for thermal insulation can reduce *affordability* for houses with low energy labels.

5.1.3. All-electric heating systems

In the all-electric system, we found a value conflict between *environmental sustainability* and *autonomy* versus *affordability* (Group 5). These systems are relatively expensive and therefore only accessible for higher-income households. Although *thermal comfort* increases due to better insulation, heat *affordability* decreases. The following three new groups of value conflicts were found.

5.1.3.1. Group 6 conflicts: Environmental Sustainability and Autonomy vs. Thermal Comfort (no increase in thermal comfort). This group of value conflicts is embedded in electric heating systems with individual heat pumps (3.1). While in Group 1 conflicts, some households benefit in terms of *thermal comfort*, this is not the case here (see Table 9). Heating costs are relatively high, which explains why mostly high-income households choose this option. These households tend to live in single-family houses rather than in duplexes and flats.

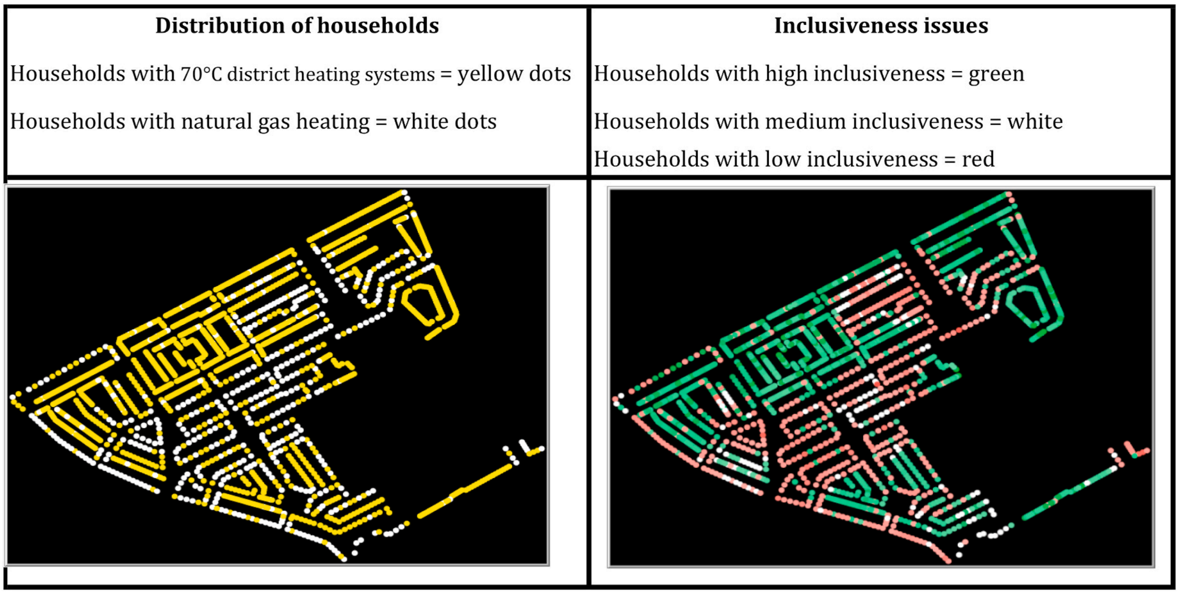

Fig. 2. Household inclusiveness with 70 °C district heating systems.

Table 7
Environmental Sustainability and Autonomy vs. Inclusiveness.

Values in conflict	Households positively affected	Households negatively affected
Environmental Sustainability Affordability	- Middle and high income - Middle and high demand - Living in single-family houses and duplexes	
vs.		
Inclusiveness	- Middle and high income - Middle and high heat demand - Living in single-family houses - Low and middle energy label	- Low and middle income - Low heat demand - Living in duplexes and flats - Tenants

Table 8
Environmental Sustainability and Autonomy vs. Affordability.

Values in conflict	Households positively affected	Households negatively affected
Environmental Sustainability Autonomy	- Middle and high income - Low and middle demand - Middle and high energy label - Living in single-family houses	
vs.		
Affordability		- Middle and high income - Low and middle demand - Middle and high energy label - Living in single-family houses

5.1.3.2. Group 7 conflicts: Thermal Comfort vs. Affordability (no increase in affordability). This group of value conflicts is embedded in electric heating systems for households who rely on individual heat pumps and electric boilers (3.3). *Thermal comfort* increases due to the use of electric boilers and better thermal insulation. Compared to Group 3 conflicts, however, no households gain in terms of heat *affordability* (see Table 10).

Table 9
Environmental Sustainability and Autonomy vs. Thermal Comfort.

Values in conflict	Households positively affected	Households negatively affected
Environmental Sustainability Autonomy	- High income - Middle and high demand - Living in single-family houses	
vs.		
Thermal Comfort		- High income - Middle and high demand - Living in single-family houses

Table 10
Thermal Comfort vs. Affordability.

Values in conflict	Households positively affected	Households negatively affected
Thermal Comfort	- Middle and high income - Middle and high heat demand - Low energy label	
vs.		
Affordability		- Middle and high income - Low and middle heat demand

5.1.3.3. Group 8 conflicts: Environmental Sustainability and Affordability vs. Inclusiveness (inclusiveness issues for higher-income households). This group of value conflicts occurs in electric systems. Compared to Group 4 value conflicts, *inclusiveness* issues apply to higher instead of lower-income households (see Table 11). This is due to the relatively high costs of these systems, and hence their lack of *affordability*. *Inclusiveness* issues are concentrated in other areas in the city district (see Fig. 3).

5.1.4. Summary of groups of value conflicts for the three sustainable heating systems

In Table 12, we provide a summary of groups of value conflicts embedded in each heating option using the agent-based models. If a group of value conflicts was found to be embedded in a certain heating

Table 11
Environmental Sustainability and Autonomy vs. Inclusiveness.

Values in conflict	Households positively affected	Households negatively affected
Environmental Sustainability Affordability	- Middle and high income - Middle and high heat demand - Middle and high energy label - Living in single-family houses and duplexes	
vs.		
Inclusiveness	- Middle and high income - Low and middle heat demand - Living in single-family houses	- Middle income - Middle and heat demand - Low and middle energy label

option, the corresponding cell is coloured red. In Section 5.2, we evaluate the impact of value conflicts in terms of social acceptance.

5.2. Evaluation of suitable district heating systems for 'de Vruchtenbuurt'

In this section, we evaluate which sustainable heating systems are most suitable for 'de Vruchtenbuurt' in terms of social acceptance. The consequences and hence the severity of embedded value conflicts on social acceptance can be anticipated by identifying scenarios of value change (see Section 3). During a brainstorming session with the co-authors we made a list of scenarios (e.g. social events, market changes, meteorological changes) for each value conflict that could result in households changing their preferences. We then created a list of the possible consequences resulting from the lack of consideration of some values. This list was created based on our experience of typical social acceptance issues in the energy domain.

Table 13 lists the scenarios and possible social acceptance issues. Both lists are illustrative and non-exhaustive but are helpful to estimate the severity of social acceptance issues. In Group 1 and Group 6 value conflicts, households may realise over time that the loss of thermal comfort is greater than they initially expected. This may lead to protests against public authorities or to households choosing to top up their current heating with less sustainable heating sources (e.g. electric heaters powered by grey electricity). In Group 2 and Group 5 value conflicts, increasing electricity and heat prices may have serious consequences for low-income households that switched to sustainable heating systems. Ultimately, socioeconomic inequalities may increase. For Group 3 and Group 5 value conflicts, investments to improve the energy labels of houses may not be reflected in house prices. Switching to sustainable heating systems may therefore involve significant financial risks. In Group 4 value conflicts, growing socioeconomic inequalities may further segregate income groups in city districts and result in tensions among households. In Group 8 value conflicts, households that switched to sustainable heating systems may conclude that they are making too many sacrifices compared to the rest of the population.

In the 70 °C district heating system, waste heat as the central heat source is more suitable as it involves the least amount of loss of in-home thermal comfort. Group 1 and Group 3 value conflicts do not occur for this subtype of heat system. Two value conflicts remain in this system. The conflict between *environmental sustainability* and *autonomy* versus *affordability* may be severe. For some households, costs related to thermal insulation and the purchase of new appliances may represent a high and risky investment. These households are also vulnerable to changing regulation on heat taxation. It is uncertain whether households will continue to be dedicated if the costs of using this heating system increase. This conflict could be addressed by subsidies and other means of financial support, although costs for public organisations may be high. Financial support could be directed towards the more vulnerable households (low-income families living in poorly insulated houses). The value conflict between *environmental sustainability* and *affordability* versus *inclusiveness* (Group 4) is less severe because higher income populations are those who suffer from a loss of affordability. Still, the fact that only this group can afford sustainable heating might contribute to a general feeling of growing socioeconomic segregation at the national level. Various social activities in support of social inclusion could be organised at the city district level, but it is unclear to what extent they can contribute to the inclusiveness of the energy transition.

The 40 °C district heating system is clearly riskier in terms of in-home thermal comfort in 'de Vruchtenbuurt'. This is because houses are poorly insulated. The use of electric boilers is more suitable as they can top up water heat to the same level as gas boilers. Three value conflicts exist in this system. The value conflict between *thermal comfort* and *affordability* (Group 3) is significant because this system requires households to purchase a large number of appliances and apply thermal insulation. While insulation contributes to greater thermal comfort, costs may be

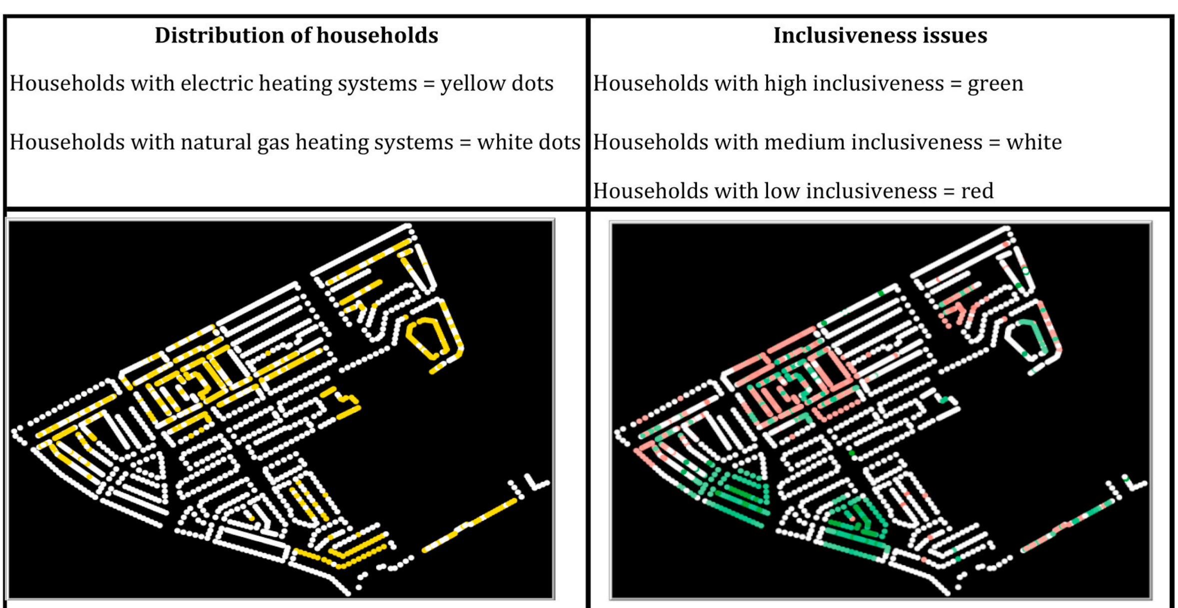

Fig. 3. Inclusiveness issues in all-electric heating systems.

Table 12
Summary of value conflicts embedded in heating systems (in red).

	Types of heating systems						
	70°C district heating systems		**40°C district heating systems**		**All electric heating systems**		
Subtypes	*1.1*	*1.2*	*2.1*	*2.2*	*3.1*	*3.2*	*3.3*
Group 1: *Environmental Sustainability* and *Autonomy* vs. *Thermal Comfort* (with an increase in *Thermal Comfort* for some households)		[red]	[red]				
Group 2: *Environmental Sustainability* and *Autonomy* vs. *Affordability* (with an increase in *Affordability* for some households)	[red]	[red]	[red]				
Group 3: *Thermal Comfort* vs. *Affordability* (with an increase in *Affordability* for some households)		[red]	[red]	[red]			
Group 4: *Environmental Sustainability* and *Affordability* vs. *Inclusiveness* (*Inclusiveness* issues for lower income households)	[red]	[red]	[red]	[red]			
Group 5: *Environmental Sustainability* and *Autonomy* vs. *Affordability* (no increase in *Affordability*)				[red]	[red]	[red]	[red]
Group 6: *Environmental Sustainability* and *Autonomy* vs. *Thermal Comfort* (no increase in *Thermal Comfort*)					[red]		
Group 7: *Thermal Comfort* vs. *Affordability* (no increase in *Affordability*)							[red]
Group 8: *Environmental Sustainability* and *Affordability* vs. *Inclusiveness* (*Inclusiveness* issues for higher income households)					[red]	[red]	[red]

Table 13
Scenarios of value change and possible social acceptance issues.

Groups of value conflicts	Possible scenarios leading to value change	Possible acceptance issues
Group 1: *Environmental Sustainability* and *Autonomy* vs. *Thermal Comfort* (with an increase in *Thermal Comfort* for some households)	- The hype of switching to sustainable heating options is over. People wonder whether the loss in thermal comfort was worth it. - Winters are colder than usual. - Planned thermal insulation work is more complicated than expected or even infeasible due to the characteristics of (old)houses.	- Lower home temperatures, leading to societal unrest and complaints to public authorities. - People look for alternative solutions: e.g. electric heaters, which are less sustainable if they use grey electricity. The grid might not be able to comply, leading to issues of security of supply. - Tensions between households that experience a loss of thermal comfort and those that do not.
Group 2: *Environmental Sustainability* and *Autonomy* vs. *Affordability* (with an increase in *Affordability* for some households)	- Energy (heat or electricity) prices increase. - Heat is taxed at the same level as natural gas and electricity. - An economic recession occurs.	- Electricity bills increase, leading to societal unrest. - Socioeconomic inequalities in the city district increase. - Tensions between households that experience a loss of heating affordability and those that do not.
Group 3: *Thermal Comfort* vs. *Affordability* (with an increase in *Affordability* for some households)	- Real estate prices do not reflect investments in thermal insulation and other heating appliances. - An economic recession occurs.	- Houses become less attractive for potential buyers; sellers lose money. - The financial situation of poorer households worsens.
Group 4: *Environmental Sustainability* and *Affordability* vs. *Inclusiveness* (*Inclusiveness* issues for lower income households)	- Growing socioeconomic inequalities - Deployment of other technologies (e.g. electric cars) further segregates high- & low-income households.	- Tensions between households living in single-family houses and those living in apartments in the city district.
Group 5: *Environmental Sustainability* and *Autonomy* vs. *Affordability* (no increase in *Affordability*)	- Energy (heat or electricity) prices increase. - Heat is taxed at the same level as natural gas and electricity. - An economic recession occurs.	- Electricity bills increase, leading to societal unrest. - The overall wealth of the city district declines.
Group 6: *Environmental Sustainability* and *Autonomy* vs. *Thermal Comfort* (no increase in *Thermal Comfort*)	- The hype of switching to sustainable heating options is over. People wonder whether the loss in thermal comfort was worth it. - Winters are colder than usual. - Planned thermal insulation work is more complicated than expected or even infeasible due to the characteristics of (old)houses.	- Lower home temperatures, leading to societal unrest and complaints to public authorities. - People look for alternative solutions: e.g. electric heaters, which are less sustainable if they use grey electricity. The grid might not be able to comply, leading to issues of security of supply.
Group 7: *Thermal Comfort* vs. *Affordability* (no increase in *Affordability*)	- House prices do not reflect investments in thermal insulation and other heating appliances. - An economic recession occurs	- Houses become less attractive for potential buyers; sellers lose money. - The city district declines.
Group 8: *Environmental Sustainability* and *Affordability* vs. *Inclusiveness* (*Inclusiveness* issues for higher income households)	- Households that switched to sustainable heating systems feel they are making too much effort compared to the rest of the population.	- Households switch back to traditional forms of heating.

high. However, this mostly concerns higher-income households since this heating system is probably not affordable for others. Similar to the 70 °C district heating system, this heating system may lead to *inclusiveness* issues (Group 4). Regulation could be changed to allow for inter-household sharing of heat and heating appliances. This could allow more households to have access to sustainable heating. The value conflicts between *environmental sustainability* and *autonomy* versus *affordability* mostly affects small households with relatively high incomes. Similar to Group 3 value conflicts, they can be addressed through subsidies. Information campaigns could provide information to households about investment risks.

In electric heating systems, using electric boilers involves the fewest changes to houses besides thermal insulation. Electric boilers can also reach same heat levels as natural gas boilers. Two value conflicts exist in this system. The value conflict between *environmental sustainability* and *autonomy* versus *affordability* (Group 4) only affects high-income households. Changes in houses are limited to thermal insulation and the purchase of electric boilers. However, heating costs may increase considerably due to higher electricity consumption. Subsidies could support the thermal insulation of houses. The value conflict between *environmental sustainability* and *affordability* versus *inclusiveness* (Group 8) also mostly affects higher-income households. Policy measures could include promoting the environmental benefits of electric boilers usage powered by green electricity. This could encourage households to pursue their efforts despite inclusiveness issues.

6. Conclusions and policy implications

6.1. Conclusions

This paper answered the following research question: *How can we assess* ex ante *the social acceptance of household sustainable heating systems at the city district level by addressing value conflicts?* We took a two-step approach. First, we identified value conflicts embedded in sustainable heating systems in specific social settings using an agent-based model. Next, we identified scenarios of value change that could lead to a lack of social acceptance and evaluated the severity of resulting acceptance issues. This approach is useful for policymakers to select sustainable heating systems for city districts and to specify additional design requirements and policy guidelines. We demonstrated this approach using a case of community driven heating initiative in the city district 'de Vruchtenbuurt', in The Hague, the Netherlands.

By taking this approach we were able to identify the risks of future social acceptance in specific city districts even if the duration and complexity of the heating system project does not allow us to predict household (non-)acceptance. The agent-based model is capable of taking the specific characteristics of households in the city district into account and evaluate how these could affect future social acceptance. For example, in 'de Vruchtenbuurt', the relative geographical clustering in terms of income and type of housing is responsible for value conflicts involving *inclusiveness* (Groups 4 and 8). Taking specific characteristics of households into account is necessary because social acceptance of sustainable heating systems in other city districts does not necessarily guarantee social acceptance in 'de Vruchtenbuurt'.

Our work has four limitations. First, we do not address all possible sources of social acceptance. As indicated in Section 3, factors related to household decision-making (e.g. attitudes, intentions, availability of information) are not included in our analysis. These cannot be accurately predicted for the entire lifetime of installed sustainable heating systems. However, the impact of these factors is that social acceptance issues could occur even if no value conflicts exist, or inversely. Public participation procedures exist to address these factors in support of social acceptance (Pidgeon et al., 2014). Second, while the aim of this work is to support social acceptance, value conflicts also have implications in terms of social justice and fairness. Some of these issues may not result in a lack of social acceptance but might still be important for selecting more sustainable heating systems in city districts. Third, we did not identify value conflicts that can also occur between city districts. Issues of *inclusiveness* could occur between more or less affluent city districts, or because some sustainable heating systems are not suitable everywhere. Fourth, we identified relevant values and their conceptualisation for the city district through expert interviews. Although this choice can create a more robust overview of the future risks of sustainable heating systems, expert knowledge may not be flawless, in particular with regard to the diversity of households and houses in the city district.

6.2. Scientific contributions

We contribute to the academic literature on energy policy by demonstrating an approach to robustly support the social acceptance of energy systems in an uncertain future. The literature on the social appraisal of technologies can be divided among social psychology and behavioural science on one side, and ethics of technology on the other. The first tends to concentrate on the immediate appraisal of infrastructures by individuals. For example, the Technology Acceptance Model (Davis, 1989) considers the impact of perceived usefulness and perceived ease-of-use. While this could be sufficient to support social acceptance in the short term, this may not be sufficient for systems for long lifespan systems. This is because households may only be confronted with potential negative effects after the system is deployed, and their preferences can be affected by other exogenous societal changes over time. The second tends to concentrate on broader societal impacts of technologies, even if they may not immediately result in a lack of social acceptance. Therefore, such analyses can point to potential future acceptance issues, even if they are not immediately revealed by households. The literature on ethics of technology is generally not concerned with the causality between a better consideration of values and social acceptance (Oosterlaken, 2014). By identifying value conflicts and scenarios of value change, we show how this relationship can be conceptualised. Agent-based modelling and the scenario discovery technique are two effective and efficient methods to carry out this approach.

6.3. Policy implications

This work addresses part of the challenge to switch from traditional natural gas heating systems to sustainable heating systems. While there is a sense of urgency in deploying more sustainable heating systems, their deployment may have serious future effects on the well-being of households (e.g. in-home thermal comfort, financial situation, social inclusion). Choices that are made today may create a lock-in effect and limit options of future inhabitants or generations to act upon their well-being. For example, choosing the 70 °C district heating system could limit possibilities to deploy more sustainable systems in the future, when 40 °C district heating technology becomes cheaper.

We have developed an approach that can help to identify more suitable sustainable heating systems by taking the specificity of each city district into account. Additionally, the approach can be helpful for the communication process with households. To our knowledge, this is the first tool that visualises in such detail the value conflicts that multiple sustainable heating options cause in specific social settings. The approach can facilitate decision-making processes and create a greater tolerance and understanding for the trade-offs that policymakers are facing.

In the light of this work, we identify three key implications for policy. First, appropriate regulation is required to guide the planning and deployment of sustainable heating systems initiated by community initiatives. Although such initiatives may contribute in terms of environmental sustainability, they may also have serious negative consequences on human well-being in the short and long term. Regulation is required to balance the values to which sustainable heating systems should comply and ensure social cohesion and well-being. Second, tailor-made policy instruments at the level of city districts are required to adjust sustainable heating systems to city district characteristics. This work shows that the characteristics of city districts in terms of housing and households affect the suitability of heating systems and hence their social acceptance. Third, sustainable heating systems should be designed to account for value change (van de Poel, 2018). Even if heating systems may seem to be accepted initially, economic, technological, and social changes may affect the suitability of sustainable heating systems over time. This might result in significant additional costs to replace parts of the existing system. The approach demonstrated in this paper can be useful for policymakers in charge of planning sustainable heating systems in city districts. It can be used to identify the lack of social acceptance resulting from the deployment of various heating systems. Design requirements and policy guidelines can be specified to account for value change in support of social acceptance.

6.4. Future research

We have three suggestions for future research. First, the approach proposed in this work could be tested for other cases. This includes other energy infrastructures, such as the deployment of the smart electricity grid. It would also be informative to test our approach in city districts that are less heterogeneous in terms of housing and households than 'de Vruchtenbuurt'. For these other cases, empirical research to identify important values and their conceptualisation for households could be more exhaustive. This could be done by means of in-depth interviews, surveys, and participant observations. Second, the approach proposed in this paper could be complemented with participatory decision-making methods. Our expert interviews to identify values and their conceptualisations in the 'de Vruchtenbuurt' may have limitations to capture of diversity of households and houses in the city district. Participatory decision-making methods could be used to get a better understanding of the specificity of a city district. Third, the agent-based model could be further extended to simulate the decision-making of households leading to issues of social acceptance. In this paper, we identified scenarios that could lead to lack of social acceptance qualitatively. Agent-based modelling is well equipped to simulate the decision-making of individuals in social contexts. This extension of the model could help to classify the severity of embedded value conflicts.

CRediT authorship contribution statement

Tristan E. de Wildt: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Visualization. **Anne R. Boijmans:** Investigation, Validation. **Emile J.L. Chappin:** Writing – review & editing, Supervision. **Paulien M. Herder:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Overview of interviewees

Interview	Organisation	Expertise
Senior policy advisor	Ministry of Economic Affairs and Climate Policy of the Netherlands	Integration of new energy systems (social, governance, and technical)
Senior policy advisor	Ministry of Economic Affairs and Climate Policy of the Netherlands	Energy markets
Head of Energy Markets and Innovation	Ministry of Economic Affairs and Climate Policy of the Netherlands	Energy markets
Senior policy advisor	Ministry of Economic Affairs and Climate Policy of the Netherlands	Acceptance of new energy systems
Policy advisor	Ministry of Economic Affairs and Climate Policy of the Netherlands	Heat transition in city districts
Policy officer	Ministry of Economic Affairs and Climate Policy of the Netherlands	Acceptance of energy transition on regional level
Research manager Energy Transition Studies	EnergieTransitie (TNO)	Smart grids, smart energy systems and all-electric districts
Advisor Energy Research and Development	Netherlands Enterprise Agency (RVO)	Pilot projects with smart grids and decentralised energy systems in the built environment
Strategy manager	Netbeheer Netherlands	Social aspects of the energy transition
Regional coordinator for the Energy Transition	Stedin	Process management in energy infrastructure
Active initiator in 'de Vruchtenbuurt' district	/	Local expertise
Active board member of 'Warm in de Wijk' in the 'de Vruchtenbuurt' district	/	Local expertise
Senior policy advisor Energy Transition	Municipality of The Hague	Local expertise

Appendix B. Interview questions

Round 1	What is your role in the energy transition?
	What other parties are you working with? What other parties are critical in this problem?
	What is your link to decentralised heating systems?
	What is your link to 'de Vruchtenbuurt'?
	What would you describe as remarkable aspects of this city district?
	What aspects (values) should be considered during the transition to a decentralised heating system?
	What specific household characteristics should be considered during the transition to a decentralised heating system?
	How do you think these characteristics influence values?
	What do you expect to be the biggest obstacle in the transition to a decentralised heating system?
	Which governance and technologies do you expect to have much potential?
	What do you expect from bottom-up initiatives? Is there enough support for these initiatives?
	Do you expect that a general approach for city districts to change to a decentralised heating system can be identified?
Round 2	What is your role in the energy transition?
	With what other parties are you working together? What other parties are critical in this problem?
	What is your link to decentralised heating systems?
	What is your link to 'de Vruchtenbuurt'?
	Do you agree with the chosen values? Are any important values missing?
	Do you agree with the chosen conversion factors? Are any important conversion factors missing?
	Do you agree with the chosen governance models and technical designs? Are any models or designs missing?

Appendix C. Household and housing data

Type of data	Data	Distribution to individual households	Source
Annual disposable income	- Distribution of annual disposable income for the Hague applied to 'de Vruchtenbuurt'	- Distributed to individual households depending on the type of housing: households living in single-family houses have the highest income, followed by those in duplexes and those in flats. - A normal distribution over each annual disposable income to compensate for the fact that the relationship between income and type of housing is not completely linear.	CBS data (CBS 2019)
Ownership	- Owners: 80.2% - Tenants: 19.8%	- Percentages of ownership per type of housing (MBZK 2019)	Data The Hague 'in cijfers' (DenHaaginCijfers 2019)
Type of household	- Single-person household: 35.4% - Couples without children: 26.2%	- Percentages of type of household per type of housing (MBZK 2019)	Data The Hague 'in cijfers' (DenHaaginCijfers 2019)

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Type of data	Data	Distribution to individual households	Source
	- Couples with children: 29.2% - One parent with children: 9.2%		
Energy label	- Data taken from map	- For houses with an unknown energy label, we assign labels using a normal distribution over the average energy label of that type of housing in 'de Vruchtenbuurt'.	Nationale EnergieAtlas (EnergieAtlas 2019)
Type of housing	- Taken from Google Maps	\	Google Maps
Surface per type of housing	- Taken from the IF Technology report	\	IF Technology (IFTechnology 2018)
Heat consumption per house	- A function of the energy label, size, and type of house	\	Thesis Dasa Majcen (Majcen 2016)
Green electricity	- Percentage of households using green electricity: 69% - Percentage of households using grey electricity: 31%	- Randomly distributed over households	Energiemonitor 2017 (ACM 2017)

Appendix D. Technological data

Costs.

	Purchase and installation costs	Maintenance costs per year	Connection costs	Consumption costs	Sources
Individual heat pump	6500 EUR	150 EUR	/	0.022 EUR/MJ	(MilieuCentraal 2019, Stedin 2019)
Collective heat pump	250 EUR/kW	7.5 EUR/kW	200 EUR	0.015 EUR/MJ	(MilieuCentraal 2019, Stedin 2019)
Collective geothermal heat	Apartments: 8000 EUR Houses: 12000 EUR	/	200 EUR	0.003 EUR/MJ	(IntGroen 2018, Schilling 2017)
Individual electric boiler	2000 EUR	20 EUR	/	0.056 EUR/MJ	(MilieuCentraal 2019)
Waste heat	Apartments: 8000 EUR Houses: 12000 EUR	/	200 EUR	0.00745 EUR/MJ	(Hers 2018, Schilling 2017, Vliet 2016)
Gas boiler	1600 EUR	70 EUR	171.97 EUR	0.025 EUR/MJ	(MilieuCentraal 2019, Stedin 2019)
Thermal Insulation	Data per m2 and energy label	/	/	/	(Hers 2018, Schilling 2017)

Costs of thermal insulation of apartments to a higher energy label (adapted from Hers 2018).

	A+	A	B	C	D	E	F	G
Currently G	441	141	116	102	80	57	30	0
Currently F	337	138	107	89	61	30	0	–
Currently E	337	132	96	75	43	0	–	–
Currently D	253	160	80	34	0	–	–	–
Currently C	267	157	72	0	–	–	–	–
Currently B	119	84	0	–	–	–	–	–
Currently A	64	0	–	–	–	–	–	–
Currently A+	0	–	–	–	–	–	–	–

Costs of thermal insulation of single-family houses to a higher energy label (adapted from Hers 2018).

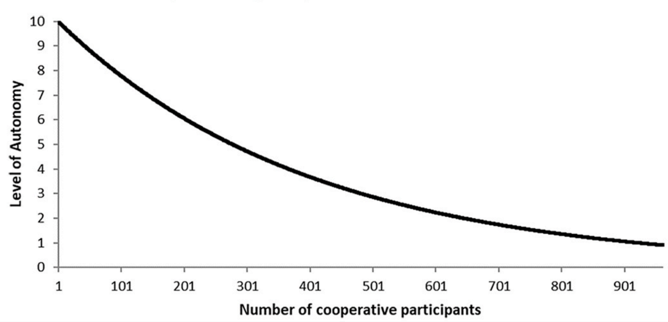
	A+	A	B	C	D	E	F	G
Currently G	303	170	140	123	96	66	33	0
Currently F	277	166	128	106	72	35	0	–
Currently E	232	147	107	85	49	0	–	–
Currently D	198	122	76	49	0	–	–	–
Currently C	218	185	69	0	–	–	–	–
Currently B	82	70	0	–	–	–	–	–
Currently A	31	0	–	–	–	–	–	–
Currently A+	0	–	–	–	–	–	–	–

CO2 emissions (adapted from MilieuCentraal 2019a).

	kg CO2 per MJ	Efficiency energy source to heat	kg CO2 per used MJ
Heat pump	0.1147	2.5	0.04588
Collective geothermal	0.1147	4	0.02868
Electric boiler	0.1147	1	0.1147
Waste heat	0	0.9	0
Gas boiler	0.0537	0.85	0.0632

Appendix E. ODD+D model description

Overview	Purpose	- To identify value conflicts in underlying sustainable heating systems
Overview	State variables and scales	- The agents have characteristics of households (annual disposable income, heat demand, housing ownership, type of electricity consumed (green or grey) and type of household) and housing (energy label, surface, and type of building). - All households and housing data remain the same for the entire duration of the model run. The goal of the model is to identify how these data affect the occurrence of value conflicts. - Various sustainable heating systems are tested. Each system is associated to purchase, installation and consumptions costs, CO2 emissions, ownership (individual, community initiative or private company), and financing (subsidy, zero-interest loan, or no public support).
Overview	Process overview and scheduling	- Setup: o 15% of agents are asked to join the community initiative, the others continue to use natural gas. o All agents evaluate the initial fulfilment of their values. - Go: o Agents try to increase the fulfilment of their individual values. At every tick, agents decide to join or exit the community initiative according to what maximises the sum of the fulfilment of their values most. All households have the same values. The fulfilment of their values might however differ depending on the household and housing characteristics and the heat consumption choice they made. o The model runs until all agents have no further opportunities to increase the fulfilment of their values (approx. 10 ticks).
Design concepts	Theoretical and empirical background	- Value Sensitive Design (Friedman1996): technologies are not value neutral but are value-laden. - Ethics of technology and value conflicts (Vandepoel2015): the realisation of some values may affect others.
Design concepts	Individual decision-making	- At every tick, agents aim to increase their overall level of value fulfilment (sum of all five levels of fulfilment of values). o Values are *Thermal comfort*, *Affordability*, *Environmental Sustainability*, *Autonomy,* and *Inclusiveness*. Their fulfilment is a number between 0 (not fulfilled) and 1 (completely fulfilled). - Agents evaluate which of the following options increase their overall level of value fulfilment most: 1. Join (or stay in) the community initiative. 2. Quit (or stay out of) the community initiative and rely on natural gas consumption for heating. - Agents calculate the best feasible option. The option is feasible if they have sufficient income to afford it. The best option is the one that maximises the level of value fulfilment most. If no option is feasible, they choose natural gas consumption.
Design concepts	Learning	- None
Design concepts	Individual sensing	- Agents look at their surroundings to evaluate the value inclusiveness: the more neighbours that have made the same heating choice (whether in or out the community initiative), the more they feel included.
	Individual prediction	- None
	Interaction	- Occurs in the model when agents evaluate the value inclusiveness.
	Collectives	- Agents belong or do not belong to the community initiative. This means that they use the same technologies for heating. The level of insulation of houses might change.
	Heterogeneity	- Agents are heterogeneous with regard to annual disposable income, heat demand, and housing ownership, type of electricity consumed, type of households, energy label, housing surface, and type of building.
	Stochasticity	- The following elements are stochastic in the model: o Randomised agent iteration. o Correlation between agent parameters (household and housing characteristics) if data for a specific household in the city district are unknown. This is essentially the case for household data: annual disposable income, heat demand, housing ownership, type of electricity consumed, type of household.
	Observation	- The model provides the correlation between the evolutions of value fulfilment for different groups of agents. Two values are in conflict if the fulfilment of value 1 increases for one group and the fulfilment of value 2 decreases for another group.

Details		- The model is implemented in Netlogo - The following functions are used: **Fulfilment of value**
		Thermal comfort We use a point system: • Individual heat pump: 0.45 • Collective heat pump: 0.45 • Collective geothermal heat: 0.55 • Electric boiler: 0.80 • Waste heat: 0.70 • Gas boiler: 0.80 Points are attributed based on the max temperature that each technology or source can provide. The level of points increases if the house is well insulated (max up to 1).
		Affordability We first calculate the sum of the following total costs per year: - NPV of purchase, installation, and network costs (including subsidy and loans) - NPV of insulation costs - Consumption costs Then the willingness to pay: annual disposable income * 'U2_threshold_disposable_income_to_affordability' Affordability is a function of the willingness to pay and the total costs per year. Affordability is 0 if costs are higher than the willingness to pay and 1 if energy costs are less than 1% of the annual disposable income.
	Implementation details	***Environmental sustainability*** This is the sum of the CO2 emissions of heating consumption compared to systems with the lowest and highest CO2 emissions for this household. Environmental sustainability is 1 if the sum is the same as the lowest CO2 emission possible and 0 if the sum is same as the highest CO2 emission possible.
		Autonomy Autonomy $= e^{-ax+\ln(1-b)+b} * mult$, where: a = U2_slope_autonomy_size_community b = 0 mult = 10 x = Number of community initiative participants 
		Inclusiveness Percentage of neighbours having made the same choice for heating consumption (either in or out the community initiative)
	Initialisation	- 15% of agents are asked to join the community initiative, the others continue to use natural gas
	Input	- Household data: annual disposable income, heat demand, housing ownership, type of electricity consumed (green or grey) and type of household. - Housing data: energy label, surface, and type of building. - Heating option: costs and CO2 emissions.
	Submodels	- No submodels

. (*continued*).

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