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Article

Unlocking Grey Scientific Data on Resident Behaviour to Increase the Climate Impact of Dutch Sustainable Housing

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Abstract
A "community of knowledge" of representatives of the housing sector in the Netherlands investigated the impact of the behaviour of residents in sustainable housing, both newly constructed and renovated stock. For this, grey scientific data were used, i.e., data and reports from non-university agencies reflecting research commissioned by civil society NGOs and commercial enterprises. The aim was to find perspectives for action (practical "rules of thumb") to increase the impact of sustainable housing on CO_2 reduction and facilitate the implementation of the Dutch national sustainability program. First, a conceptual framework and research model were created to generate the relevant research questions for the sustainable construction sector. An innovative research approach was used where data from academic non-university researchers were enriched by university academic researchers. Experiences with the methodology used are: (a) It implicitly places the many factors that influence sustainable resident behaviour in context; and (b) it makes clear that data from such research can complement university research with useful data from practice, data that are scientifically difficult to use because they are mostly derived from stand-alone case studies. The perspectives for action that were generated are: (a) Sustainable technologies must add new useful functionalities for acceptance; (b) sustainable supply must be tailor-made because households differ and tenants behave differently from homeowners; (c) decision-making about sustainable investments is not only based on financial factors; (d) residents are reluctant to become involved, so it is important that (e) the people representing contractors should be reliable; and (f) people want personalised plans and on-time delivery. Finally, the collected reports turned out to be focused on practice and therefore provided less theoretical information about the rebound effect.

Keywords
CO_2 reduction; community of knowledge; energy transition; resident behaviour; sustainable housing

Issue
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1. Introduction

As the year 2030 draws closer, and 2050 already looms in the distance, it becomes more urgent for all countries to work towards the CO_2 emission reduction targets in the UN Agreements of Paris and Glasgow (United Nations, 2015, 2021). In 2018, the Netherlands started roundtable consultations between government, business, universities, and interest groups of citizens, the so-called "climate tables." These "climate tables" were set up to develop feasible approaches to achieve the goals set in the UN Paris Agreement (Ministry of Infrastructure and Water Management, 2019) and they primarily focused on mitigation and adaptation measures. The climate table on housing and construction took the behaviour of residents into account because its influence on the results could be large, as studies into the rebound effect indicate (de Ridder et al., 2016). However, resident

behaviour in relation to climate change is a relatively new area of research. For example, Dutch initiatives such as The Green Village, a field lab for sustainable innovation (https://thegreenvillage.org/en), and the SenseLab (https://www.tudelft.nl/en/architecture-and-the-built-environment/research/research-facilities/senselab), have been set up by TU Delft to gain more insight into this. And there are comparable research projects in other countries. However, given the task at hand, there is an urgent need for insight into the behaviour of residents, in order to develop perspectives for action.

This urgency has been increased because of the lawsuit brought against the Dutch government by the NGO Urgenda. In 2015 and 2018, Urgenda took the initiative to sue the Dutch government for its lack of adequate measures to achieve the goals of the Paris Agreement (De Rechtspraak, 2015, 2018). The lawsuit was followed up by an implementation program in the 2019 Urgenda report (Minnesma, 2019). That the Dutch population realises more and more that action is needed on climate change is illustrated by a survey conducted by the NIDO institute: The authors interviewed 300 randomly selected Dutch people and concluded that the percentage of people concerned about climate change had increased by 15 percentage points in the past three years, up to 63% (Dalen & Henkens, 2019). This was supported by a survey by Statistics Netherlands (CBS, 2021). Another indicator of a change in public attitude towards climate change can be found in the level of "flight shame," which has increased from zero to 13% in the same period (Bos & Rusman, 2019). The growing focus on climate change in the student population is reflected in the nationwide student strikes on February 7 and March 14, 2019, following the appeal of the young climate activist Greta Thunberg in Sweden (Nagtegaal & Peek, 2019).

Despite these signals of a positive change in attitude towards climate change in the Dutch population, the CO_2 emission reduction results of sustainable living appear to be lagging. This can be at least partly attributed to resident behaviour (Oosterhuis et al., 2014). The 2016 report of the Amsterdam Auditor's Office on the results of energy-saving measures in social housing can therefore be seen as a wake-up call regarding this issue in the Netherlands (de Ridder et al., 2016). A survey of 5,000 home renovations in 2011–2014 conducted by the auditors' office concluded that, despite investment in renovations in sustainable energy, energy consumption has hardly decreased; this is due to insufficiently attuned resident behaviour. Despite the annually increasing urgency (Netherlands Environmental Assessment Agency, 2014), renovations for sustainability appear to be focused more on production and less on the influence of resident behaviour on the ultimate mitigation result (Netherlands Environmental Assessment Agency, 2014). Although research into the influence of resident behaviour has increased over the years, the emphasis is mainly on the acceptance of sustainable investments in housing renovation, as shown, for instance, by Ebrahimigharehbaghi (2019), and less attention is given to the situation once housing is occupied.

Driven by the urgency of the situation in the Netherlands and in view of the lack of focus on resident behaviour, a "community of knowledge" on behaviour in sustainable housing was set up. This consisted of representatives of housing associations, municipalities, energy companies, a gas distribution company, a housing developer, a company involved in sustainable community-building, and universities. In 2017, this community of knowledge made an inventory of available research and data, both scientifically and semi-scientifically produced by scientists in non-university research centres (the so-called grey data), about the influence of resident behaviour on the mitigation effect of sustainable housing. It covered both new housing and housing renovations of the existing housing stock. The aim was to make these results available to those working on this topic in the construction and academic sectors. In 2019, the results of this inventory were evaluated with the support of TU Delft (Overtoom & Ortiz, 2019). These are summarised here. The conceptual framework is described in Section 2, the research questions in Section 3, and the data collection and analyses in Section 4. The conclusions can be found in Section 5, with an answer to the research questions in Section 5.1, followed by the evaluation and comments in Section 5.2, and some reflections in Section 6.

2. The Conceptual Framework and Research Model

In the Dutch situation, most of the energy people use at home is electricity for appliances and natural gas for central heating (Druckman & Jackson, 2008; Gill et al., 2010; Santin et al., 2009). Depending on whether the house is newly built or sustainably renovated, residents display a diversity of positive and negative behaviours in sustainable living (Burton, 2012). According to Sanders (2014), residents also copy the behaviour of others, which can reinforce positive and negative behaviour in groups and thus influence residents' decision-making, their sustainable choices, cooperation with neighbours, and their investments. Additionally, Tamis and Staats (2014) have pointed out that visible, positive experiences with sustainable technologies in a neighbourhood can make residents more likely to also invest in this technology.

However, due to a lack of appropriate behaviour in residents, the intended energy savings are not always achieved (Caird et al., 2008; Gatersleben et al., 2002; Gill et al., 2010). Such non-adaptive behaviour also disturbs the opportunities for sustainable action of organisations and enterprises involved, such as municipalities, energy-producing and distributing industries, housing associations, and housing entrepreneurs (Hens et al., 2015; Rooijers et al., 2006). The differences between predicted and actual energy consumption are currently also a concern for municipalities and the national government, as

these prevent the agreed targets to be met by 2030 and onwards. The conclusion is that when preparing the renovation aimed at CO_2 reduction, non-adaptive resident behaviour must be taken into account (Ministry of the Interior and Kingdom Relations, 2011).

2.1. The Conceptual Framework

There seem to be two types of resident behaviour both of which are part of the rebound effect. The direct effect occurs when a person refuses to adopt more sustainable behaviour—in this case, for instance, the correct use of the installed technology. The indirect effect occurs when financial savings are redirected to environmentally unfriendly products or behaviours (Nadel, 2012, 2016)—for instance, households investing savings from heating on the purchase of a new car, or using savings incurred from the installation and use of solar panels on more lighting in the house. The occurrence of the rebound effect can be directly traced back to the classical paradox from economic behavioural theory described by Jevons (1865). There is still only little knowledge of the impact of the rebound effect (Dütschke et al., 2013), especially with regard to behaviour linked to housing. The general notion that people base their choices on economic consideration (Fouquet & Pearson, 2012; Thomas & Azevedo, 2013) as well as on social-psychologically driven daily practice (Hofstetter et al., 2006) is less of an influence.

In practice, both types of rebound effects occur simultaneously and are intertwined. As far as scientific research on this theme is available, the rebound effect seems to stand in the way of sustainable results in the Dutch housing sector (Santin, 2012). Therefore, to ensure a shared focus at the start of the community of knowledge mentioned before, a conceptual framework on the rebound effect was discussed and elaborated (see Figure 1). Based on the work of Sanders (2014), the group confirmed that collaboration between residents and professionals can only be productive if both seek and implement a joint approach. This is illustrated in Figure 1 (right).

Explanation of the conceptual framework:

1. The rebound effect (Figure 1, left): When residents in sustainable housing perform a behaviour that counteracts the desired behaviours, due to a lack of abilities (horizontal axis: left-"low" ability, right-"high" ability) and/or motivation (vertical axis: bottom—"low" motivation, top—"high" motivation), this produces the rebound effect (red arrow). The desired behaviour, on the other hand, starts with growing awareness of the lack of sustainability in the present situation, followed by increased participation in sustainable decision-making, resulting also in the encouragement of more sustainable behaviour in others.
2. Behavioural change can only lead to sustainable results if residents and professionals from government, institutes, and companies achieve collaboration. This is illustrated in the diagram on the right, where residents adopt a longer-term orientation (horizontal axis) and expand their focus from the immediate living environment to that of the city and the region (vertical axis). Professionals, on the other hand, also will have to adapt in order to meet the residents halfway (grey-shaded area).

2.2. The Research Model

The research approach of this community of knowledge differs from a more conventional research approach, which would mean opting for new scientific research. Instead, the approach entails the use of grey data as scientifically as possible, i.e., research results from non-university institutions. The research model has been developed by the community of knowledge and is illustrated in Figure 2. In addition to research from universities and related research institutes, there are numerous research results, documents, and reports on energy-saving and sustainable behaviour in sustainably built housing produced by more commercial research institutes. The research is usually carried out on behalf of organisations and companies active in the Dutch

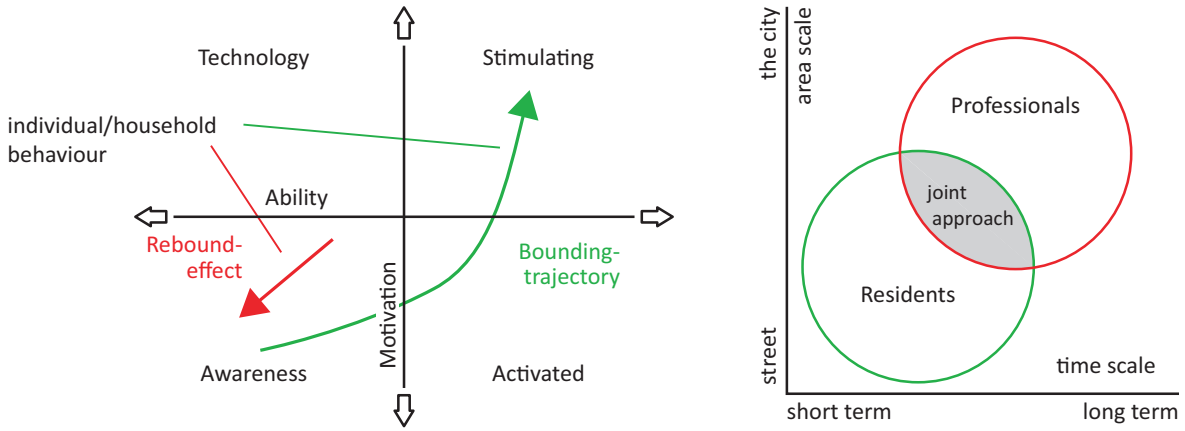

Figure 1. Conceptual framework of the rebound effect (left) based on joint approach (right).

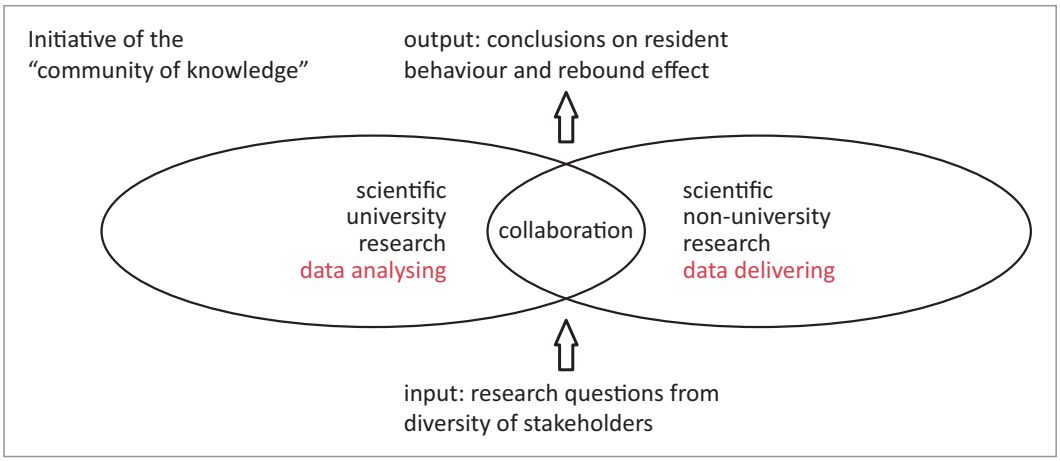

Figure 2. The research model visualising the setting of the research and the relations between the different factors.

housing sector; government institutions, municipalities, semi-commercial institutes, social housing organisations, and commercial enterprises that work on increasing the sustainability of housing in the Netherlands. Most of this research is conducted by consultancies or by academics from non-university research organisations. In practice, this research is not made available to universities but is kept for their own use, for commercial purposes, or because it is simply not considered compatible with university research. The community of knowledge has taken the initiative to make these reports accessible for analysis in a scientifically sound manner. This analysis of already available data can help to gain more insight into the aforementioned perspectives for action to attain more sustainable results in the housing sector in the Netherlands in the short term.

This model shows how scientific non-university data (i.e., the research results from academics at non-university bodies) is analysed by scientific university research, to answer the questions posed by a diversity of stakeholders in the sustainable housing and construction sector in the Netherlands. This approach of mobilising a research community of participants from different disciplines working jointly can be seen as a form of transdisciplinary research (Hadorn, 2008). This research methodology provides adequate new approaches for common problems. The composition of the community is continuously monitored.

3. The Research Question(s)

Considering the approach of the study as explained in Section 2, which aims at generating practical perspectives for action, the community of knowledge elaborated the central research question as follows: How can grey data, i.e., non-university scientific research, be used to generate relevant knowledge about the behaviour of residents in sustainably built housing to improve mitigation results and thus facilitate and accelerate the national energy transition? And which perspectives for action does this provide for the Dutch housing and construction sector?

In order to develop the intended practical perspectives for action, the group has elaborated a number of sub-questions. To this end, two workshops were organised. Companies and universities involved with housing and construction—the main actors—were invited to participate. The first result was an inventory of already known perspectives for action, which were clustered thematically in an axis field diagram developed during the workshops (see Figure 3). These thematic clusters were then discussed to identify the remaining questions, which led to nine sub-questions.

The relevant sub-questions which were developed in the two workshops follow from the discussed perspectives for action. These are:

1. Which environmental/situational factors influence sustainable behaviour?
2. Will installation companies continue to sell old-fashioned installations?
3. How to prevent obstructive behaviour by residents (consciously and unconsciously)?
4. Do residents know how to use new installations?
5. Do residents want to use new installations?
6. On which scale do households participate in government sustainability campaigns?
7. Do residents accept sustainable government policy?
8. Under which conditions do households invest in sustainable technologies for their homes?
9. On which scale will households and their neighbours invest in sustainable technologies?

All these questions are related to the main three themes that together influence the decision-making of households of resident behaviour, sustainable technology innovation, and government involvement.

4. Data Gathering and Analysis

Research reports (Sections 2 and 3) were collected by community of knowledge participants by approaching colleagues within their own organisation and asking

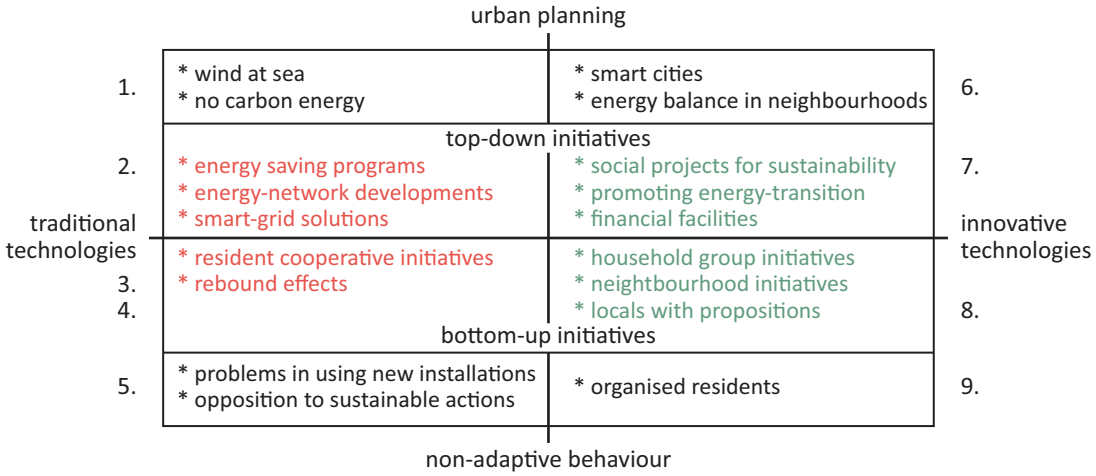

Figure 3. Diagram for "sustainable resident behaviour," with clustered action-perspectives and sub-questions numbers. Notes: The (exemplary) behaviour of residents of sustainable housing was placed in a diagram with opposites by the participants: bottom-up and top-down initiatives (vertical), and traditional and innovative technologies (horizontal). To supply the scale of the individual and the city in the vertical axis, "urban planning" is featured at the top of the diagram and "non-adaptive behaviour" at the bottom. The diagram shows positive (in green) and negative (in red) examples of sustainable resident behaviour.

other befriended organisations to do the same. In total, about 100 documents were received. These were fed into a database for the study and the results were discussed in the community regarding diversity and quality. Once the stream of documents petered out, the active collection was ended and a check was done on whether enough and sufficiently diverse documents had been received for the first analysis.

4.1. Review of Documents: Core Group

Before the assessment, all documents were scanned for duplicates and content relevance (Dutch context, sustainability, and housing were the main criteria for relevance). Leaflets and brochures were left out of consideration, so that research reports remained, which all turned out to be from the period 2011–2018. The resulting documents ranged from user segmentation images, internal company presentations, and research reports from commercial research firms to government or municipal policy documents, including new research proposals. This selection process ultimately resulted in 40 documents of sufficient quality and relevance for the intended analysis and for answering the sub-questions and the central research question.

For a proper identification of these 40 documents, they were examined in the following categories: (a) the source organisation, (b) whether the government was involved, (c) method of publication, (d) the methods of the research, and (e) the focus of the research (residents, policymakers, housing associations, etc.). The results are presented in Table 1.

Table 1. Summary of documents reviewed in detail.

	Research office	Educational institution	Municipality	Company	Housing association	Governmental	Total
Creators	18	13	6	8	3	5	53
	Government	Other					
Issued By	10	3					13
	Planning document	Review	Research paper	Case study	Presentation	Other	
Document Type	5	4	13	7	2	7	38
	Quantitative	Qualitative	Mixed-methods	Other			
Research Type	11	9	7	10			37
	Residents	Government	Housing associations	Marketing companies	Other		
Aimed At	4	9	2	3	3		17

Note: Some documents fit in more than one column.

The next step in the document review was to identify the predominant topics covered in these documents regarding aspects of sustainable living behaviour (see Table 2). Using this pre-selection as a guideline, three themes appeared to be leading in the 40 selected documents: (a) the type of motivation used to exhibit environmentally friendly behaviour (comfort, energy, social, and financial), (b) the behavioural differences between people in relation to sustainable results, and (c) research into methods that are used to motivate people to adopt sustainable behaviour.

The actual researchers and authors of these documents were either employed at a consultancy or worked for an internal research department of an energy company or a housing association and did their work in collaboration with universities. There are 11 documents for which the research appears to have been conducted by a government agency.

It is notable that these documents are especially interesting because "real-life" situations have been investigated. Most documents lacked a theoretical framework and adequate control of the results. The quality of these documents is different from that of scientific research.

Most of the selected 40 documents mention behaviour as an important factor in reducing energy consumption, which confirms the importance that science has attached to behaviour in reducing energy consumption over the past 20 years (Jackson, 2005). In most documents, however, behaviour is treated very generally, without specific references to particular technologies or investments. Describing behaviour and categorising it also turned out to be a common theme in these reports. The motivations most often cited for acting sustainably turned out to be saving energy and money and improving the comfort of living indoors.

5. Conclusions

5.1. The Research Questions Answered

The questions formulated by the participants of the community of knowledge (Section 3)—based on the conceptual framework and research model as summarised in the diagram of clustered perspectives for action (Figures 1, 2, and 3)—are shown to be mostly oriented on either technology or behaviour. Therefore, the answers to these questions are elaborated following these orientations. They are accompanied by the aforementioned scientific literature which endorses the conclusions. The nine formulated sub-questions are brought together in two new sub-questions (Sections 5.1.1 and 5.1.2).

5.1.1. Technology-Oriented: Answering Research Questions 2, 4, 5, 8, and 9

One of the two reformulated questions is: How do people interact with specific technologies? Or, in a slightly different formulation: How can people be motivated to use and interact with sustainable technologies? This is important for housing construction to be effective in the transition to sustainability.

The first, more detailed conclusion based on the 40 selected reports is as follows: In order to be accepted and thus successful, sustainable technologies must add new useful functionalities. The technology must be given a so-called "comfort factor" for the user, as is also apparent from the result of a marketing expert meeting (Zoetbrood & Gotz, 2015), adapting personal preferences in the performance of a product (Aune, 2001; Chatterton, 2011). One of the reports, a study of 6,000 Dutch households, shows that previous positive experiences motivate households to take more sustainable next steps (van Lidth et al., 2014). Research among 514 households in the city of Utrecht showed that higher-educated people make such steps more easily (de Kleijn & van Leerdam, 2011). An investigation into the entry-level arguments for purchasing a hybrid heat pump shows that the instructions for new technology must be tailored to the user, supplied with sufficient information, simple, understandable, and up-to-date (Engberts & Overdiep, 2016). This means that financial arguments are not always decisive for purchasing new technologies (Zoetbrood & Gotz, 2015). This is confirmed by research among the households of 12 neighbourhoods in Den Bosch, which showed that cheap loans for sustainable investments hardly influence decisions to make these investments (Fudura, 2014). Although a survey among 2,500 respondents confirms that "comfort" properties of sustainable products stimulate their purchase, other examples quoted point to financial advantages, improvement of comfort, and a positive contribution to the environment. Exemplary behaviour of others also appears to stimulate such purchasing behaviour (van der Werf et al., 2015; van Welzen & van Delft, 2014; Vringer et al., 2014). Where households and individuals differ, customisation is desirable to encourage people to make sustainable investments and to choose relevant new technologies. For example, children within a household can have a decisive influence (de Wilde, 2018; van Lidth et al., 2014; van Middelkoop, 2014).

In conclusion, sustainable technologies must fit into people's lives so that they will benefit them and will align with their personal motivational goals. For sustainable

Table 2. Summary of topics of documents reviewed in detail.

Motivation Type					Differences	Energy Reduction Method		
General	Comfort	Energy	Social	Financial		Behaviour	Technology	Personal action
8	10	11	4	14	15	22	13	12

technology development, this means that there must be room for different approaches, depending on technology, housing type, and household type.

5.1.2. Behaviour-Oriented: Answering Research Questions 1, 3, 6, and 7

The other reformulated question is: How can the behaviour of residents be positively influenced to reduce energy consumption so that they will participate in and support local initiatives towards sustainability? Second, what is the effect of campaign interventions?

Sustainable behaviour appears to have an influence, but the case studies found in the 40 selected reports indicate that this is not easy. A pilot among 250 households in the cities of Zwolle and Breda, for example, showed that residents are open to the provision of new information, as long as this information is diversified according to the needs of different groups of people and households (NL Agency, 2013). Projects in which residential blocks were renovated one by one show that tenants want predictable planning and homeowners want personalised plans (Netherlands Environmental Assessment Agency, 2014). Positive feedback from others, like neighbours and acquaintances, also appears to stimulate making sustainable choices (Aune, 2001) as well as contribute to positive community formation (Fischer, 2008). It is also apparent from interviews held among households and experts across the Netherlands that there is an interest in a "sustainable customer journey" (a roadmap to becoming more sustainable) with trust as the most important factor, regarding the information as well as the representatives of contractors, landlords, and the government (de Wilde & Spaargaren, 2017). Research conducted in 12 neighbourhoods in the city of Den Bosch shows that good results can be achieved in neighbourhoods for which sustainable supply is still completely new (Fudura, 2014). Polled interventions tend to stimulate sustainable action, according to research in a diversity of Dutch neighbourhoods (Straver et al., 2017). One difference that crops up repeatedly is between tenants (usually of social housing) and homeowners, with homeowners more likely to invest in sustainable technologies. Tenants are more cautious and expect their landlord to do the investments (van Lidth et al., 2014; van Middelkoop, 2014; Vringer et al., 2014).

Unfortunately, no practical examples of the rebound effect were found in the 40 selected documents, whereas the documents specifically mentioning the rebound effect were papers published in academic journals (Aydin et al., 2013, 2015; Boulanger et al., 2013).

5.1.3. Perspectives for Sustainable Action

The most promising perspectives for action are: (a) Sustainable technologies must add new useful functionalities for acceptance, and (b) must be user-friendly and customised to the needs of different households, with specific attention to the differences between tenants and homeowners; therefore, (c) financial arguments must be used less predominantly in campaigns. It also appears that (d) residents are sensitive to the quality of information provided and that (e) the representatives of contractors, landlords, and the government must appear reliable, (f) people want personalised plans and delivery on time, and (g) there is power in repetition: People are more sensitive to the sustainable message when it comes from several different senders, and will make sustainable choices if they trust and know those people.

5.2. The Methodology Reflected

The research of the community of knowledge (Sections 1 and 2) aimed at a double objective: (a) to stimulate the provision of perspectives for direct action, and (b) to evaluate the research design in which data from practice (grey data) was used, with a scientific approach to the analysis of these grey data. The ultimate aim was to contribute to the acceleration of creating sustainable housing in the Netherlands, taking into account the need for building one million new homes in the Netherlands in the coming years, in addition to the necessary sustainable renovation of approximately 3.5 million homes (Ministry of Infrastructure and Water Management, 2019).

5.2.1. The Research Methodology

The central question about the research methodology used is: What does this methodology add to traditional academic research methodologies? This question should be addressed both in the data collected and the results of the analysis. With regard to the collected data, it can be noted that the useful data from the scientific approach turned out to be mostly from location-based case studies which were elaborated by academics or advisors to municipalities and housing associations. The useful reports were few in number and many of them were not prepared in a sufficiently sound scientific way, which made it difficult to substantiate the conclusions. Therefore, only 40 documents made it to the selection.

On the other hand, these reports provided very pure information directly related to the source and based on research among households in neighbourhoods and districts. They were mostly small-scale stand-alone case studies. Second, the focus of most reports and underlying research was on practical sustainable action and less on the effectiveness of government incentives. In principle, these reports offered a fresh perspective and pointed toward new results and insights. The actual outcome, however, is that the research results of this new approach largely confirm what is known from scientific research. The second aim of the study has thus not been achieved. The mutual confirmation of the different research methods, on the other hand, can also be seen as valuable and a basis for repeating the research on a larger scale.

6. Reflections

6.1. Interactive Database

During the evaluation session held in 2019, it was suggested that if this research approach were to continue, a new and interactive database should be developed together with the participating bodies. This would encourage more active participation, as well as sharing and discussion of the results with the participants during the data collection, potentially resulting in a wider variety and higher quality of the reports provided. This would also increase the chance of new perspectives for action.

6.2. Exchange of Knowledge

The documents that the participants submitted were not only from their own companies and organisations but also documents originating from governments and universities in the collection. This indicates that there is a one-way use of scientific research for research from practice on behalf of companies and organisations that work in the field of the sustainable housing construction sector (see Figure 4, left).

When the community of knowledge came together to reflect on results, participants put forward the impression that the aforementioned "research from practice" carried out by non-university research centres is considered less relevant by the universities, and thus little or not included in university research. Actual two-way traffic in the exchange of information is preferable, with universities including results of more practically-orientated research in their own studies. Construction companies require scientific reflection on their day-to-day practice, so they can optimise their contribution to sustainable housing (for illustration of this approach, see Figure 4, right).

Acknowledgments

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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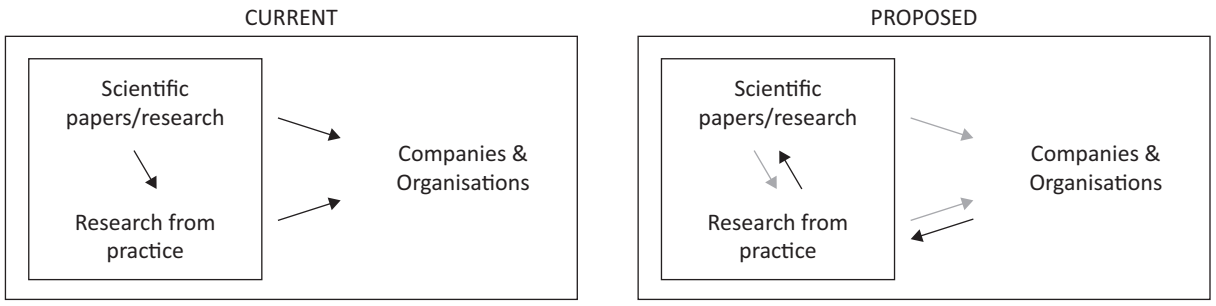

Figure 4. Visualisation of sustainable housing data exchange: Current (left) and proposed (right).

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