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Exploring PV Adoption by Non-Residential Property Owners: Applying Social Practice Theory

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ABSTRACT

This article explores the emergence of PV adoption practices among non-residential property owners in Sweden to deepen insights into PV diffusion and accelerate a renewable electricity transition. It applies a social practice theory approach to show how different practice elements need to come together to establish a PV adoption practice.

Twenty-five semi-structured interviews were conducted with private and public non-residential property owners in southern Sweden. The results show that about half of the property owners had PV systems installed for a long period and had developed a PV adoption practice. These property owners had energy and environmental goals formulated, interacted with tenants, established routines within the company, aggregated relevant knowledge, established trusted relationships with PV installers and considered PVs a mature technology that supported the PV adoption process. On the contrary, first-time installers and non-adopters without an established PV adoption practice were missing these elements.

This study is the first step towards understanding PV adoption as a practice for non-residential property owners. It contributes to an analysis of the elements that are required for a PV adoption practice to emerge. The practical relevance of the study is that it can facilitate and support non-residential property owners to adopt PV systems and contribute to a renewable electricity transition.

Keywords

Photovoltaics (PV);
Practice theory;
Technology adoption;
Non-residential property owners

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1. Introduction

Photovoltaics (PV) is important for climate change mitigation, as electricity generation from renewable energy is key to lowering carbon emissions [1]. To reach national and international goals for increased use of renewable energy and reduced greenhouse gases, there is a need to accelerate the transition to green electricity [2,3]. PV systems are promising in this regard, as they are flexible in size – being used for both large- and small-scale applications [4]. They can be applied in different locations, meaning they can be used for residential and non-residential buildings or bigger PV parks. According to forecasts by the International Energy Agency, there is significant potential for PV adoption in homes and non-residential buildings (e.g., commercial buildings, and industrial facilities) [5]. There are great hopes there will be an increase in the numbers of prosumers (consumers producing their own electricity) in Europe [6,7] as a whole and in the Nordic countries [8]. However, there is still a big implementation gap, and the potential for an increase in PV adoption is large [9,10].

PV adoption in Sweden is a recent phenomenon, and this study aims to investigate how a PV adoption practice emerges. Three groups of property owners are investigated, where one group have had PVs for a longer

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period, one is a group of more recent adopters, and one is a group of non-adopters of PV panels. The three groups' adoption practices are compared to identify similarities and differences. The aim is to understand how various elements of a practice need to come together to establish a PV adoption practice. For this aim, the following research questions were formulated:

- Why do owners of non-residential buildings in Sweden decide to install or not install photovoltaic systems, and how do elements of practice theory (engagement & meaning, know-how & habits, institutionalised knowledge & explicit rules, technology & material structure) influence these decisions?
- What changes to these four elements could be introduced to potentially increase the adoption of PV panels among reluctant non-residential owners?

Applying social practice theory to PV adoption for non-residential buildings is a novel approach that can deepen the understanding of PV diffusion and accelerate PV adoption by property owners, thereby contributing to a renewable electricity transition.

2. Practice Theory as a Framework for Understanding PV Adoption

Practice theory can contribute to an understanding of how a group or collective can associate with an adoption practice, as an alternative to focusing solely on individuals [11]. Practices are defined as "coordinated entities of sayings and doings that are held together by different elements, and that make it possible for practices to be collectively shared across time and space" [12, p. 64]. This article thus focuses on how PV adoption becomes constituted as a practice [13]. According to Feldman and Orlikowski, it is important to focus on how practices are constituted, and researchers need to "engage with the core logic of how practices are produced, reinforced, and changed, and with what intended and unintended consequences" [14, p. 1241].

Practice theory has often been used to investigate everyday practice or consumption in households or by individuals, for example through studying homeowner retrofit practices [11], residential heat comfort practices [15], stand-by consumption in households [16], pro-environmental behaviour change [17], energy consumption practices in households compared to workplaces [18], and the effects of integrating ICT into everyday life on energy consumption [19]. There are examples of studies using practice theory to investigate organisations and actors others than individuals and households, such as the practice of policymaking in the UK transportation sector [20], or the professional practices of different actors in building renovation within an organisation [21]. Other scholars who have incorporated practice theory in the domain of organisational studies include [14,21–26].

Nicolini [26] discusses how a practice approach can be central to understanding organisational and social phenomena. In Nicoloini's view, 'connected situationalism' focuses on chains of performance and their relationship in space and time, rather than on a single scene of action. Performances, in this perspective, can only be understood if the nexus at which they come into being is considered. What happens in a specific situation is linked to what is happening in another place and time (past or present), enabling the investigation of large-scale phenomena instead of only focusing on how single activities are performed (compare and see also [20]). In practice, this means that PV adoption needs to be studied in its context, where, for example, past environmental goals or strategies must be considered to understand why a practice emerges. This approach has been applied in this study.

According to Schatzki [23], an organisation may include several different practices, such as a customer service practice, an advising practice, and a meeting practice. An organisation has a 'practice memory', which refers to a structure that persist from past to present. Schatzki proposes that an organisation's memory is made up of various practice memories, and guides professionals' performance of actions. A practice can also change intentionally or unintentionally [22]. PV adoption in Sweden is quite a recent phenomenon, and thus this study aims to investigate how a PV adoption practice has emerged.

Within the different applications of practice theory, various authors have used different versions of the elements that hold a practice together (for an overview see Gram-Hanssen [16, p. 154] or Reindl [27, p. 46]. The elements used in this article are based on Gram-Hanssen [15,16], although they have been slightly revised. Gram-Hanssen [15,16] distinguishes between "know-how and habits" and "institutionalised knowledge and explicit rules", whereas others combine these into one element referred to as "competencies"(e.g. [13]). In this article, Gram-Hanssen's distinction is applied due to its more

detailed differentiation, which makes it possible to distinguish between, for example, PV policies, rules and regulations, and information versus existing practical know-how and embodied habits developed in organisations [28]. Thus, the following elements are the focus of the analysis:

- **Engagement and meaning:** What the practice means and how it is valued, referring to aims, beliefs and expectations
- **Know-how and habits:** Practical knowledge about how to carry out and perform a practice, as well as routines
- **Institutionalised knowledge and explicit rules:** The ease of navigating existing knowledge and information, policies, rules, and regulations)
- **Technology:** Material infrastructure, or the technologies or gadgets that make the practice possible, desirable and sensible [25].

The four elements are shown graphically in Figure 1.

The empirical data were analysed through the lens of these four elements that form a practice. Property owners who have adopted numerous PV systems will be compared with those who have adopted few or none, and their similarities and differences in terms of the four elements will be analysed to determine which aspects of each element are needed for an adoption practice to emerge.

3. Method and Material

This article focuses on the accomplishment of a PV adoption practice, which requires a method that capture how an adoption practice is established. Qualitative research is a method used to gain an in-depth analysis of social phenomena in their natural setting [29]. Therefore, this study used qualitative semi-structured interviews. Interviews allow probing questions, and since the purpose was to understand the role of emerging practices in PV adoption, they are a suitable method [30]. The interviews included questions about the adoption process. Although conducting interviews limits the ability to make universal generalisations across different contexts, it provides richer, context-related data, which is more valuable when discussing how an adoption practice emerges [31].

The data used in the analysis consisted of 25 semi-structured interviews, conducted with property owners of non-residential buildings in the autumn of 2019 and spring of 2020. In qualitative research, the goal is not statistical representation but rather the exploration of a phenomenon from different angles and perspectives. Additionally, theoretical saturation was reached with these interviews. [29,32]. To contact property owners, there was a collaboration with the industry organisation Fastighetsägarna Syd ('Property Owners South'); in addition, a Google search was conducted,

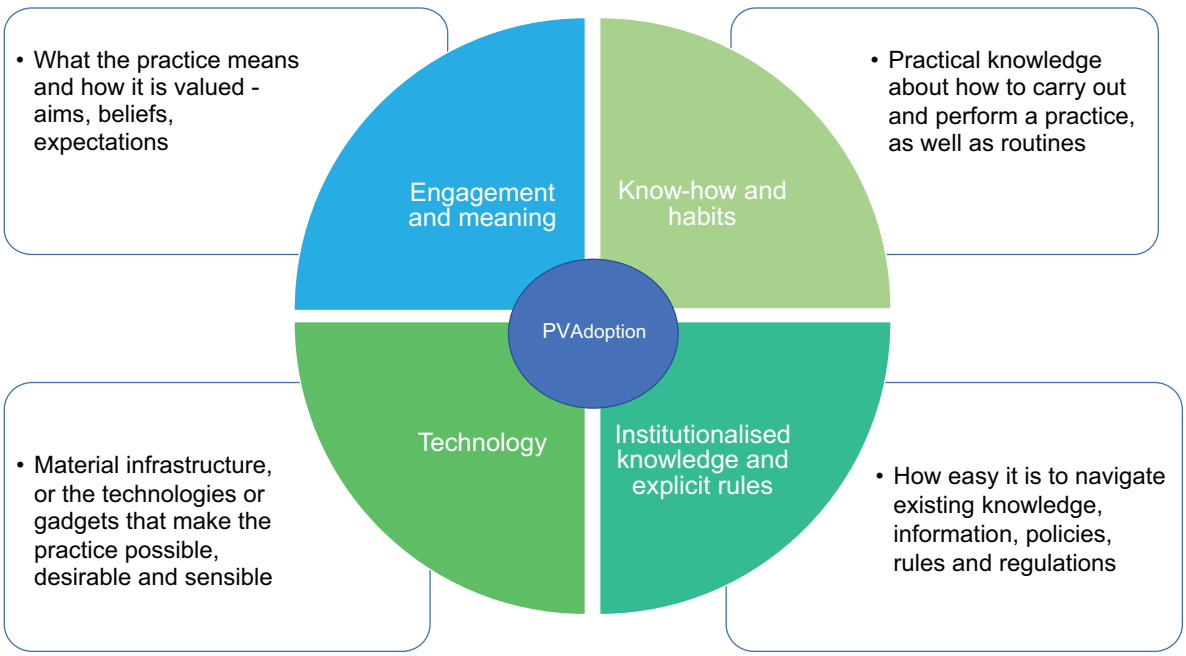

Figure 1: Elements holding a practice together.

and the Swedish Internet-based Yellow Pages (Eniro) were used.

A total of 10 public and 15 private property owners were interviewed. The interviewees, who were responsible for PV adoption, had different roles within their organisations. They included CEOs, environmental and energy managers, energy specialists, engineering and technical managers, technical project leaders, solar cell coordinators, and electrical consultants. Among the interviewees, 22 property owners had installed PV panels and three had not. See Table 1 below.

Typically, the longer a property owner had PV panels installed, the more panels they had (Table 1). The interviewees were divided into three groups: 'property owners with numerous PV systems', 'property owners with few PV systems' and 'non-adopters of PV'. These groups are described in more detail in Tables 1 and 2. Twelve interviewees had more than three PV panels installed, and these had been installed a couple of years ago; this group is called 'property owners with numerous PV systems'. Ten property owners had one to three PV panels installed relatively recently; this group is called 'property owners with few PV systems'. Three property owners had decided not to adopt PV, or at least not at the time of the interviews.

Three non-adopters were interviewed, which is a relatively low number, but the rationale for a qualitative study is to delve deeper into specific issues. The aim is

Table 1: Overview of property owners. Green: Property owners with PV systems installed for a long time. Blue: Recent adopters of a few PV systems. Grey: Non-adopters of PV.

Nr	When	Number of PV panels	Who	Public-private	Types of buildings
1	Since the early 2000	10	P-O-1	Public	Non-residential and apartments
2	2005	35	P-O-2	Public	Non-residential
3	2007	70	P-O-3	Private	Non-residential
4	2008	Expanding; 50 in the whole country so far	P-O-4	Public	Non-residential
5	2008-2009	15 in operation, 2 just completed, 4 additional planned	P-O-5	Public	Community service properties
6	2009	More than 30	P-O-6	Public	Non-residential and apartments
7	2010	26	P-O-7	Public	Non-residential and apartments
8	2012-2013	Less than 10	P-O-8	Private	Non-residential and apartments
9	2013	21	P-O-9	*Public*	Non-residential
10	2014	11	P-O-10	Private	Non-residential
1	2015-2016	1 small	P-O-11	Public	Non-residential and apartments
2	2015-2016	1, working on the 2	P-O-12	Private	Non-residential and apartments
11	2015	6	P-O-13	Private	Non-residential
3	2016/2017	1, working on the 2	P-O-14	Private	Non-residential and apartments
4	2017	1	P-O-15	Private	Non-residential and apartments
12	2017	7	P-O-16	Private	Community service properties
5	2018	3	P-O-17	Public	Non-residential and apartments
6	2019	Just installed 1	P-O-18	Private	Non-residential and apartments
7	2019	3	P-O-19	Private	Non-residential and apartments
8	2019	1	P-O-20	Private	Non-residential and apartments
9	2020	1	P-O-21	Public	Non-residential and apartments
10	Installing 2020	Soon 1	P-O-22	Private	Non-residential and apartments
1	Not adopted		P-O-23	Private	Non-residential and apartments
2	Not adopted		P-O-24	Private	Community service properties
3	Not adopted		P-O-25	Private	Non-residential

to achieve rich data and thick descriptions, enabling insights into the nuanced practices and perceptions surrounding PV adoption. This depth allows for a better exploration and understanding of emerging practices compared to a larger but more superficial dataset [32]. This study captures a broad spectrum of experiences and organizational contexts. Such diversity ensures that the findings reflect varied approaches to PV adoption, including those who commonly adopt PV systems and those with minimal to no adoption.

Including the non-adopters is meaningful for this study despite their small number, as this group provides critical contrast and insights into the barriers and reasons for deciding not to adopt PV systems. The main focus of the analysis is on the adopters and how the PV practice emerges. While the non-adopters serve primarily to contrast the adopters.

Cresswell and Cresswell [32] highlight that to ensure validity and rigour, it is also important to include negative cases in the analysis. Therefore, the inclusion of non-adopters helps to increase the validity and rigour of this study.

While including just three non-adopters in the study is justified for a qualitative study, certain issues can be critiqued as well. There is a risk that the data does not fully capture the spectrum of reasons why they chose not to adopt PV systems. Further research is recommended to address this.

Table 2 shows the characteristics of the three different PV adoption groups: property owners with numerous PV systems installed for a long time; those with few systems installed who started installation relatively recently; and non-adopters. It details when they began to adopting PVs, how many systems they have installed, whether they are private or public property owners, and the types of buildings they own.

Anonymity for the interviewees was ensured; thus, no names are provided alongside quotations, and no property owners are named. All interviews were recorded, transcribed, and analysed with the help of the data analysis software NVivo.

For the analysis, a qualitative content analysis was conducted. First, inductive coding was performed, followed by deductive coding using the practice theory elements as a coding scheme [33]. The results from the second deductive coding are presented here. To ensure validity and rigour in this study, certain strategies by Creswell and Creswell [32] were followed. First, the data collection and analysis processes were rigorous and followed established procedures for qualitative studies and semi-structured interviews. Additionally, rich, and thick descriptions were used, negative information was presented, peer debriefing was employed and member checking was used for clarification from the interviewees if needed. Furthermore, to enhance validity and rigour, all researchers involved participated in the coding and analysis. The result from coding are presented below.

Table 2: Summary of the adopters and non-adopters.

Numerous PV systems installed	**Few PV systems installed**	**Non-adopters of PV**
• Property owners with PV systems installed for a longtime • Earliest adopter in the early 2000s • 12 property owners (7 public, 5 private) • Non-residential buildings only (6), both non-residential and apartment buildings (4), community service buildings (2) • 6+, up to 70 PV systems installed • Developed a PV adoption practice	• Recent adopters of a few PV systems • Started adoption in 2015/2016 • 10 property owners (3 public, 7 private) • Non-residential and apartment buildings • Testing PV or just getting started -1 to 3 systems installed • Just developing a PV adoption practice	• No PV systems adopted • 3 property owners (all private) • Non-residential buildings, non-residential and apartment buildings, community service buildings • No PV adoption practice

4. Results: The Elements of Practice in the Three Adoption Groups

In this section, the different elements that hold a practice together concerning each adoption group presented in Table 2 are analysed. The section is divided according to the four elements holding a practice together: 'engagement and meaning', 'know-how and habits', 'knowledge and explicit rules', and 'technology'. For each element, the first adopter group (numerous PV systems installed) is presented first, followed by the second group (few systems installed) and finally the third group (non-adopters).

4.1. Engagement and meaning

Engagement and meaning are seen as an important element holding a practice together. Here, they refer to goals and aspirations related to the environment and energy, tenant engagement and involvement, and other

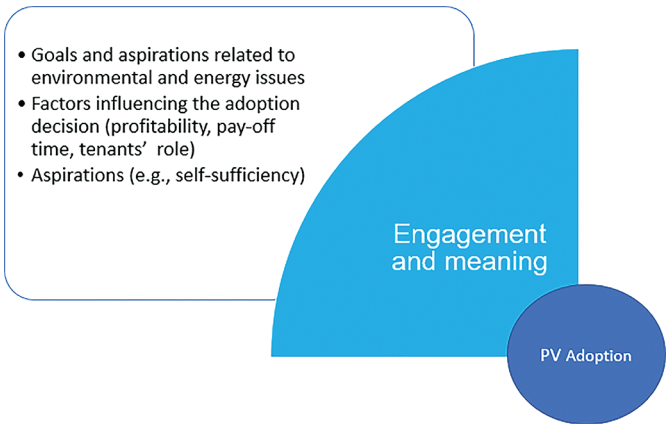

Figure 2: PV adoption – Engagement and meaning.

factors influencing the adoption decision such as views on profitability and pay-off time, as well as future aspirations like self-sufficiency (Figure 2).

Property owners with numerous PV systems had formulated environmental and energy goals and took various measures to achieve them. For example, they bought green electricity such as wind and solar, used company service cars that ran on biogas or electricity, environmentally certified their properties, and continuously worked on greener energy solutions in their buildings (e.g., updated installation systems such as heat recovery ventilation or energy-efficient pumps, additional insulation, or new windows). PV played an important role in this work.

Their tenants' interest in PV varied according to the property owners. Generally, tenants were considered to be positive and curious about the installed PV panels, with no complaints. Some property owners experienced low interest from tenants, which they found disappointing. Others received requests from tenants to install PV panels, often because many tenants had their own environmental or energy goals to fulfil. One property owner said, for example: *"We have customer meetings with them, and they want to brand themselves with PVs. It's a suggestion from them"* (P-O-5).

Some of the property owners wanted to showcase the PV panels and educate others about renewable electricity production and consumption. For instance, one property owner said they had visited schools to talk about PV systems, which they also hoped would create a positive feedback loop for the children's parents.

There were also some difficulties raised regarding PV adoption and the property's tenants. First, there is the question of how long a tenant will rent a property. If a tenant wants PV panels installed, the question is whether the next tenant will also want them. Short-term contracts make long-term planning more difficult. Secondly, property owners must find a suitable solution regarding the tenants' electricity supply. The tenants usually own the electricity supply account and are therefore responsible for paying their consumption. There were different solutions to this situation. One option was for tenants to pay a small rent surcharge for the PV installation, which was compensated by having a lower electricity bill. The second option was for the property to own the supply account and distribute the electricity costs to the tenants.

Despite some profitability concerns, most property owners said that PV panels were profitable in the long run. There was variation in terms of what was considered an acceptable pay-off time. Overall, this group accepted a longer pay-off time compared to the other two groups. The longest accepted pay-off time in this group was 13 to 15 years. For non-adopters, the longest accepted pay-off time was eight years. The first group also argued that the price of PV panels had decreased significantly in recent years.

Even if profitability was highlighted as important, strong environmental values supported the decision to adopt in this group. One property owner said, for example: *"You want the money back /.../. But that is not the main reason, it is probably more of an environmental concern, that we produce the energy that we can use for cooling instead of buying other electricity"* (P-O-3).

Achieving some degree of self-sufficiency was important for most property owners, but most did not want to be completely off-grid. They were interested in microgrids, and two property owners had buildings connected to a microgrid.

The property owners with few PV systems, similar to those with numerous PV systems, had various environmental and energy goals and worked in different ways to achieve them. For example, they worked on reducing their climate footprint, improving energy solutions for the buildings (e.g., installing heat pumps), used biogas cars for company service cars, making environmentally conscious material choices, and purchasing green electricity. Two property owners installed PV systems while simultaneously developing an environmental strategy. This group did not consider PV installations as the most important part of their environmental work.

In contrast to the first group, only two property owners in this group said they had noticed interest in PV panels from the tenants. All the others said there was no interest or demand from tenants. However, even if their tenants were not interested, they experienced interest

from the public, and again schools were seen as an important target group. Some of the property owners with numerous PV systems had already started educational initiatives regarding their panels.

In this group, PV panels were considered to be starting to become profitable. Members of this group noted that they were beginning to observe a decrease in the price of PV panels and shorter pay-off times: *"If you go back five or ten years, it was even more expensive, and then it was even harder to motivate yourself... to do this because it was difficult to recoup the investment"* (P-O-18). However, a few mentioned that the pay-off time was still almost too long for them, and it did affect their decision to adopt or not. One property owner said that they did not fully believe in the calculations they had received from the PV installers. The believed that if all variables were included in the calculation, PV might not be profitable. They viewed their PV installation more as a test to gather actual data (P-O-15). Some mentioned that subsidies were necessary to make it profitable.

Some property owners had the ambition to become partly self-sufficient in electricity, while for others, this was simply not possible due to their high electricity consumption. Microgrids were of interest to almost all property owners in this group, but not all of them knew what a microgrid was.

In the non-adopting group, only one property owner had had environmental and energy goals formulated since the early 2000s, and they actively worked on energy issues in various ways. For instance, they focused on smart management of their houses, made efforts to reduce energy consumption with new installations, changed their heating systems to geothermal heating, and used electric vehicles as service cars. This company had received requests from tenants to install PV panels but decided to find alternative solutions for them, such as owning shares in wind power plants. This interviewee believed that he was well-informed and had a good overview of PV-related information. His view was that PV was an immature technology that was not profitable.

The other two property owners in this group had no environmental or energy goals formulated and worked little or not at all with these issues. One of them mentioned that environmental and energy goals had not traditionally been their focus, but since 2019/2020 they had been under new management, which had started to investigate these areas, although they had not yet set any specific goals. PV panels were not seen as profitable; the costs were considered too high, and pay-off times were seen as too long. The other one had no experience working with environmental and energy issues but was investigating ways to reduce their operating costs, such as electricity and heat consumption. A few years ago, they had considered installing PV on the roof of one of their buildings, but ultimately deemed it too expensive.

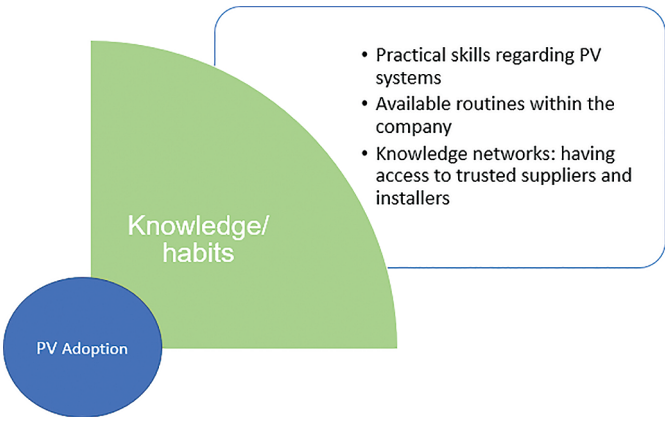

Figure 3: PV adoption – Know-how and habits.

4.2. Know-how and habits

Know-how and habits can be seen as crucial in shaping a practice [11]. Here, it refers to various skills and knowledge acquired by property owners in their work with PVs. Aggregated knowledge and knowledge networks are essential for creating or sustaining know-how [34] (Figure 3).

Since installing PV panels, the property owner with many PV systems has aggregated a considerable amount of related information and experience, learning how to maintain them in the process. They had established routines and procedures for PV adoption. Additionally, they often designate a special 'PV group' or person within the company responsible for PV installations. Some mentioned plans to increase the number of people within the company working with PV. Emphasising the importance of knowledge networks, the property owners highlighted the crucial role of maintaining good relationships with professional, knowledgeable, and trusted PV planners and installers when adopting PV. Some considered this to be the single most important factor when installing PV systems.

In terms of know-how and habits, there was a stark difference between property owners with numerous PV systems and those with few. The property owners with few PV systems had not yet aggregated much knowledge around PV and had not formed any relevant routines within their companies. Three property owners in this group were in the process of establishing routines

for adoption. One company had begun building a knowledge base within their organisation. Another found it challenging to obtain information on PV, and there were many aspects they still needed to learn and understand. They had recently hired a project manager to focus on PV installations and initiated the development of routines and knowledge gathering.

Most of the property owners with few installations had not yet found trusted PV planners and installers. They were in general rather sceptical towards existing PV planners and installers, questioning the information they received and doubting their trustworthiness. They experienced that there were too many PV planners and installers with different opinions in the market, making it difficult to find a reliable source. One property owner expressed: *"They are like pool traders: there are many cheerful amateurs, but you get very different answers from some […] It's not easy to know what to think"* (P-O-19). However, three property owners who mentioned that they had already found a PV supplier they trusted.

The non-adopters had no aggregated knowledge or routines as they had not yet adopted PV.

4.3 Institutionalised knowledge and explicit rules

Knowledge and explicit rules refer to how the property owners engage with existing information on PV, including various policies, rules, regulations, and subsidies. This includes regulations and standards governing procedures, as well as technical knowledge of PV systems [21] (Figure 4).

The property owners with numerous PV systems generally agreed that there was plenty of information available on PV installation, and that the information was of good quality. Only a few thought the existing information was confusing or that there was a lack of it. Often, they found specific information lacking, such as one property owner of a community service building who pointed out the absence of information on fire security.

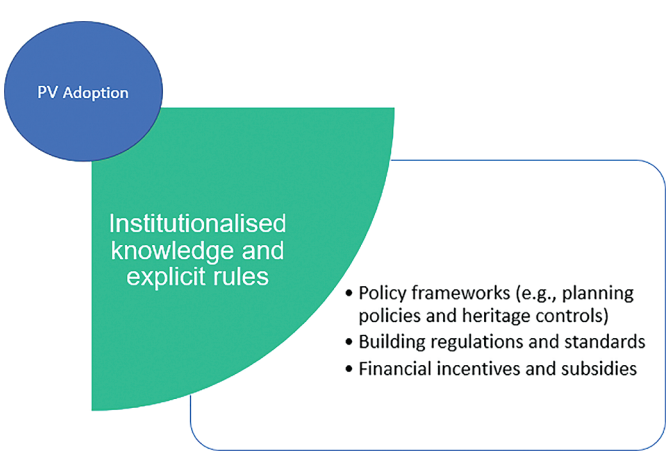

Figure 4: PV adoption – Institutionalised knowledge and explicit rules.

This group had no issues finding information on rules, regulations, and legislation. The exception was those who generally had problems navigating information; they found it to be a jungle of rules and regulations. However, all were critical of the fact that rules and regulations were constantly changing. Some rules and regulations were seen as a hassle and counterproductive, such as building regulations, and in particular, the 255-kW tax rule was seen as counterproductive for greater PV diffusion. The 255-kW tax rule (now changed to 500 kW) required property owners to pay taxes for all installations over 255 kW, and all the property owner's PV installations are included in the 255 kW, i.e., it is the sum of the installations on all buildings owned by the property owner. Almost all the interviewees agreed that the tax rules for PV systems were counterproductive for greater PV diffusion. *"Remove the hassle around laws and rules and make laws and rules easier for both individuals and companies. Simplify it, remove VAT and taxes and yes, just make it easy"* (P-O-7).

This group did not rely on subsidies for their PV installations. Although all applied for subsidies, they did not consider them a decisive factor and stated that they would have installed PV systems even without them.

Even though the property owners with few PV systems also saw themselves as well-informed, many experienced existing information on PV installation as a jungle. They reported encountering contradictions and struggled with the multitude of concepts and terms to be learned. *"There is still a lot of ignorance on this [...] The lack of knowledge… the availability of good knowledge is very difficult, in this case [...] So it is necessary to somehow change the system so that people understand it, that I understand it and get a holistic understanding of it"* (P-O-20).

Property owners also felt that rules and regulations were complicated, changed too often, and did not support PV diffusion. For instance, building permits were viewed as a barrier to PV adoption. One property owner described the serious discussions they had had with the City Planning Office about the colour of their PV installation (blue vs. black), which they considered unnecessary since they were on the eighth floor where no one could see the panels anyway. Additionally, most

interviewees also viewed the 255-kW tax rule as counterproductive and restrictive. However, three property owners were unaware of the 255-kW rule (P-O-17, P-O-18, P-O-21).

Subsidies were regarded as positive and, for some, crucial in making PV installations profitable. *"No, it has not been [profitable]. But as I said, we get the subsidies and then we can make it"* (P-O-14). However, this group criticized the long waiting time to get approved for subsidies.

One of the non-adopters said that he was well-informed and had no issues with information regarding PV; his reluctance stemmed from the perception of PV as an ineffective and immature technology that was not profitable. The other two non-adopters were less informed. One of them mentioned that the reason for not adopting PV was the absence of subsidies, despite subsidies being available for years.

4.4. Technology

This element concerns whether the property owners were satisfied with the PV systems, how well the technology worked for them, their views on maintenance, and their opinions using batteries in combination with PV panels (Figure 5).

The property owners with numerous PV systems had between six and 70 PV systems installed and they were generally satisfied with their installations. Some mentioned encountering issues during the maintenance of the PV panels, although these were considered normal and not problematic.

Often, new buildings were chosen for PV panel installation as it was seen as technically easier and thus more profitable. Additionally, it was challenging to find suitable buildings where the demand and production of electricity were compatible. This was important because it was more profitable to use the electricity produced in the building than to sell it to an energy utility. One property owner emphasised that they would have expanded their PV installations already if it had been more profitable to sell on the market (P-O-10).

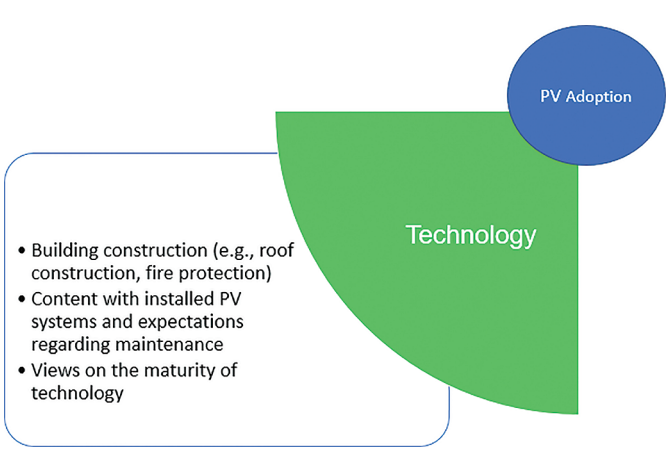

Figure 5: PV adoption – Technology and material structure.

Interest in PV technology itself was an important factor behind PV adoption for some, involving the testing of a new technology: *"We test a lot of solar cells that come on the market, both integrated and those made of glass, and we try to install them on our metal roofs and so on"* (P-O-3). Additionally, two property owners were testing a system that included PVs and batteries.

The property owners with few PV systems generally expressed satisfaction with their installed PV systems. However, many of them had only recently installed the PV systems and were still evaluating their performance, unable to provide comprehensive feedback on their functionality. They viewed this period as a learning process, involving understanding how to use and maintain PV systems. Some property owners had plans to expand and adopt more PV systems.

Additionally, property owners also commonly emphasised that it was easier to install PV panels on newly constructed buildings compared to existing ones. Some found it challenging to find a suitable building where electricity demand and production were compatible, as selling electricity back to the grid was not considered profitable.

Regarding batteries, they were mainly regarded as positive, but still too expensive to be considered profitable. One interviewee had a battery installed (P-O-14), while another questioned whether batteries were environmentally friendly. An additional issue raised was the safety using batteries in terms of fire hazards.

The non-adopters differed from the adopters in their perspectives. The consensus among them was that the technology was not yet mature enough, effective, or trusted as something that work reliably. *"My perspective is probably that I do not want to take the lead […] on these new technologies and see that they work, that you are not involved as a guinea pig. That they are stable, durable, maintenance-free, or easy to maintain. So, when […] you have got a stable product then I would probably be more interested than I am today"* (P-O-24). They were generally sceptical and preferred to wait for newer PV technology that is cheaper and more efficient.

The one property owner in the non-adopter group with environmental and energy goals disregarded roof-mounted PVs as inefficient technology but could in future imagine buying the PV sunflower solution[1] combined with batteries. However, at the time of the interview, this was too costly and not profitable for them. They could imagine potentially owning shares in a PV park, but in their opinion, the technology is simply not effective enough for that.

Another non-adopter had previously worked at a different property where PV systems were installed. This interviewee emphasised that these previous organisations had issues with the systems, noting problematic maintenance such as burnt circuits and PV damaged caused by snow shovelling. These issues demonstrated that the technology was not yet well developed. Furthermore, this interviewee remarked that their current employer had safety concerns about the roof as a working environment. Consequently, this property owner was not interested in owning PV shares. The third non-adopter stated that they had not considered owning PV shares but acknowledge that it might be an option in the future.

5. Concluding Discussion

In this section, the results and research question are discussed, conclusions are drawn, limitations of the study are presented and suggestions for future research provided. Additionally, practical recommendations are given.

This study examined the development of PV adoption practices among non-residential property owners in Sweden through the lens of social practice theory. It reveals that property owners who have adopted PV systems for a long time have already developed a practice of PV adoption where the four elements of a practice are integrated. The study contributes to the understanding of the necessary aspects for PV adoption by comparing them with those who have installed fewer or no PV systems, identifying the aspects that many have been overlooked. Consequently, policy recommendations can be more tailored to a company's stage in the adoption process.

To address the first question, namely why owners of non-residential buildings decide to install PVs and what role the elements of practice theory play, a figure based on practice theory was created to illustrate the elements that need to come together to establish a PV adoption practice.

The property owners who had numerous PV systems installed had integrated engagement and meaning, know-how and habits, institutionalised knowledge and explicit rules, as well as technology and material structure benefitting a PV adoption practice as discussed by Shove et al. [13]. By interviewing the property owners, this study could contribute to a detailed understanding of the aspects of each element that needed to be present for an element to become established.

Property owners with numerous installed PVs showed a comprehensive integration of all four elements, whereas non-adopters and those with fewer installations did not have all these elements in place. The study indicates the aspects in each element that were missing, which can be used when developing policy means to increase PV adoption. This is depicted graphically in Figure 6.

To form a PV adoption practice, all four elements need to come together and certain aspects need to be present within each element.

In the element of "engagement and meaning", the property owners needed to formulate concrete environmental and energy goals and adopt measures to achieve them, ensuring that tenants were also engaged and interested. Additionally, PV systems were perceived as profitable with short pay-off times, and achieving self-sufficiency was to some degree the goal. Similar issues are also discussed by Palm [36].

In the element of "know-how and habits", the existence of habits or routines for PV installation within the company was vital. The property owners had aggregated knowledge of PV installation and often designated a special group or person to work with PV installation. It was found that PV adoption was a learning process, and once one PV system was installed, a significant barrier was overcome because the organisation had learnt how to navigate the PV market. Additionally, good connections to knowledge networks such as PV suppliers and installers, were of paramount importance. The significance of knowledge networks was also explored by Karvonen [34] as well as the importance of latent networks by Heiskanen et al. [7]. Some interviewees even highlighted this as the most important issue.

The element "institutionalised knowledge and explicit rules" relates to obtaining information regarding PV and

[1]The sunflower PV system is "smart" and ground-mounted including a sun tracker and other high-tech features [35].

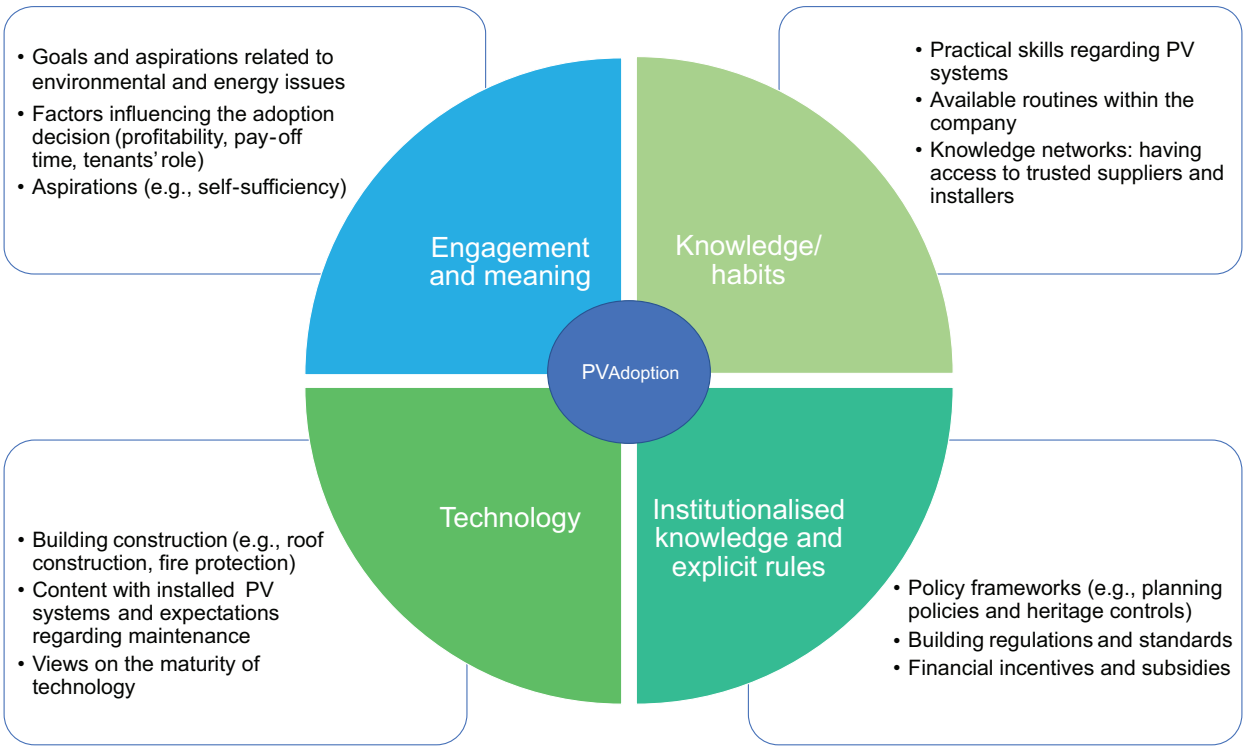

Figure 6: PV adoption practice based on the results from the interviews.

the importance of knowing how to search for and find relevant information. This element also includes the importance of navigating changing regulations and legislation and feeling comfortable with the dos and don'ts.

In the element of "technology and material structure", the property owners must see PV as a mature technology, be content with their installations, and consider some maintenance issues as normal. Another factor that can contribute to the formation of a practice of PV adoption is whether an existing building allows for it and whether the electricity demand and production of a building are compatible. Similar issues were also researched by Reindl and Palm [25].

When all these elements come together, a PV adoption practice is formed. However, as demonstrated by the comparison of the three groups, the creation of a practice is a process that can span many years. The results of this study indicate that once a PV adoption practice is established, it becomes much easier to invest in more PV panels in the future, thus enhancing PV diffusion.

5.1. Practical recommendations

This section focuses more on the second research question, i.e. what changes about the elements could be introduced to potentially improve the adoption of PV panels among reluctant non-residential owners?

Engagement and meaning

The PV adopters, with numerous PV systems installed, usually had decided environmental and/or energy goals for the company and adopted measures to achieve them. An intervention could be to work with the company's branding and incorporate environmental or energy goals within their corporate mission [37] This could serve as an important first step to establishing a PV practice.

Another intervention could be to challenge the perception of PV adoption solely as a cost, without considering the benefits of installing PV panels. Often, when something incurs a cost it is viewed as a barrier. However, this overlooks the protentional benefits of adoption energy-efficient technology, which includes relatively short pay-off times [38]. Working to assess both costs and benefits, along with leveraging levies and other financial support mechanism, might be an important measure to lower the threshold for companies to adopt PV panels [39].

It might also be helpful to enhance adoption by encouraging property owners to actively engage with their tenants about the benefits of PV, as the role of the tenants is also important.

Know-how and habits
One suggestion is to enhance knowledge sharing and support networks. It would be beneficial to promote the creation of platforms or networks where property owners can share their experiences, challenges, and best practices related to PV adoption. Facilitators could, for instance, be industry associations or public agencies, and one could work with, for example, workshops or online forums.

Another important barrier to overcome is to improve access to trusted suppliers and installers as this seemed to be difficult for the adopters with only a few installations. It can be assumed that this would be a hurdle also for non-adopters if they decide to install PVs in the future. One could focus on developing a certification or vetting system for PV installers and suppliers, managed by industry organisations or government agencies to support property owners in finding reliable suppliers and installers.

Institutionalised knowledge and explicit rules
One suggestion is also to focus more on developing sector-specific guides and toolkits or rather enhancing knowledge about already existing ones. The energy agency has created the so-called solar portal, which was not known to many.

One crucial step towards more widespread PV adoption is to simplify and harmonise regulations and to reduce complexity and inconsistencies, as many interviewees expressed. Thereby, clear guidelines on subsidies and the application to receive them were also desired. Simplifying the subsidy application process could make it easier to adopt PVs even though the property owners with numerous PVs installed no longer relied on subsidies.

Technology
Those without a PV practice often assume that the technology is not mature or yet well-developed, which is related to perception rather than experienced problems. A relatively cheap intervention would be to target those with no or a few PV systems with information about the installation and maintenance of a PV system (compare also [40]). This intervention should, however, also be combined with working with networks and clusters to diffuse information and knowledge of how other companies have worked to establish a PV adoption practice and how property owners could benefit from this [41]. During the interviews, the adopters emphasised the importance of these learning networks.

Integrating PV with other energy efficiency measures is another approach to help increase adoption. It would, for instance, be effective to promote a holistic approach to building renovation, one combining PV adoption with other energy efficiency measures.

5.2. Limitations and future research
One limitation of the study is the small sample of non-adopters. Despite the small size of this group, they still provide valuable insights when investigating what elements needed to come together to form a PV practice. This means both the property owners with few installations and non-adopters could function as a contrast to adopters with numerous installations. In future studies, it would be interesting to test this developed framework to analyse PV adoption practices in a quantitative study on a much bigger data set where the three groups were also more similar in size. Furthermore, it would be possible to expand the sample and include residential properties, such as multi-family dwellings or houses. It would also be valuable to expand the geographical area, studying other countries or conducting a cross-country comparison. Another interesting future study would be to study disrupted PV adoption practices, where it can be established that a PV practice once existed but for some reason vanished.

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