The installer in the post-industrial city

Energy transitions in Gothenburg and Rotterdam

Erasmus University Rotterdam

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1. Introduction

The study plugs into wider debates on the twin transition towards a green and digital future[1], and challenges linked to inclusive (or ‘just’) energy transitions and energy poverty. One specific challenge is a shortage of installers. European industry associations indicate the need for 500.000 heat pump[2] and even one million solar panel installers[3] by 2030 to meet the EU’s renewable energy targets. At the same time, installers are a hard-to-reach group for policy actors. Thereto, we put installers, firms that install, maintain and repair the backbones of our energy- and heating infrastructures, in the centre of our analysis. In contrast to large energy utilities, Big Tech firms and (digital) start-ups, installers have received limited attention among academia and policymakers[4,5].

Aim and research dimensions

The project aims to increase our understanding on the role of installers in urban energy transitions and the challenges they face. We also intend to provide concrete policy recommendations to support installers to overcome these challenges and to accelerate energy transitions. To do so, we explore the following research dimensions. Firstly, we explore how cities affect installers, whereby we differentiate between the urban and institutional context of cities. Secondly, we identify the major challenges installers and their customers face, and what the role of frugal innovation is to overcome these challenges. Frugal innovation refers to simplifying of products, services, and business models in resource-constrained environments[6]. Thirdly, we elucidate how digitalisation affects installers’ practices and business. We use these dimensions to provide barriers and drivers that affect installers and energy transitions.

Research questions

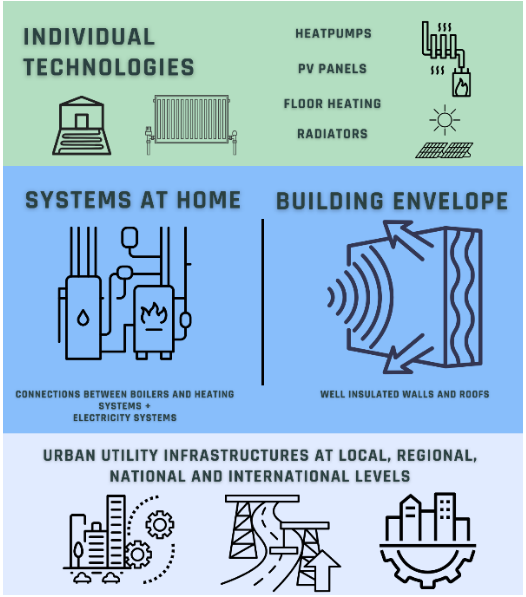
Based on these aims, the project encompasses the following sets of research questions:

1. How can **cities** support installers’ practices and energy transitions? How does the urban context affect installers? How does the institutional context affect installers?
2. What is the **role of installers** in energy transitions? What are the major **challenges** of installers and their customers?
3. How does **digitalisation** affect installers’ practices, and accordingly, influence urban energy transitions? What are drivers and barriers of digitalisation?
4. What is the role of **frugal innovation** to overcome challenges of installers and their customers? What are drivers and barriers of frugal innovation?

Method and focus

We focus on electrical and heating installers working on existing residential buildings. Buildings are the largest single energy user in the EU and 75% of the building have a poor energy performance[7]. Therefore, improving energy efficiency ('energy retrofitting') of existing buildings is essential to reach the EU's climate goals and to counter energy poverty and injustice. We differentiate four technology layers where installers have to deal with when providing retrofitting services (see Figure 1).

Figure 1: Technology layers



Source: Own elaboration

The study draws on case studies of installers in the post-industrial cities of Gothenburg (Sweden) and Rotterdam (The Netherlands). For both cities we do not limit our analysis to the municipal borders, but take into account the larger regions of the Province of South Holland (Rotterdam) and Västra Götaland County (Gothenburg). The study is based on 57 semi-structured, in-depth interviews with installers and other actors in their ecosystem, including manufacturers, Internet of Things (IoT) software providers, wholesalers, housing corporations, energy utilities, public authorities and other actors. We complemented our interview data with desktop research and a visit to an installers trade fair in The Netherlands, a district heating manufacturer in Gothenburg and participated in two sessions of the learning community energy transitions Rotterdam. Finally, we organised two validation workshops: one in Gothenburg and one in Rotterdam.

Structure

We structure our findings along the research questions. Moreover, we have added a section based on potential new roles of installers in energy transitions and end with a list of policy recommendations and limitations to our study.

2. How can cities support installers?

Table 1 shows that the two cities largely differ in the urban context. However, Gothenburg and Rotterdam have a similar population size, are both growing cities (implying a growing market for installers), do not perceive installers as a key sector (which can be explained by heterogeneity and small size of installers, sub-contracting practices and that installers are part of other sectors like ‘construction’ or ‘energy’) and an increasing energy injustice and shortage of installers.

The municipalities of Gothenburg and Rotterdam also share the challenge to reach installers. The majority of the installers are small and operate under the radar of policy actors, whereas the few large installers and industry associations seem to mainly interact with higher governmental levels. The two municipalities also share the wider sustainability goal of realising a net-zero city. That means, Rotterdam and Gothenburg go beyond the goal of improving heating- and energy-efficiency and also strive to realise a circular economy. However, Rotterdam does so on a slower pace and is challenged with the natural gas phase-out. Furthermore, the institutional context differs widely which affects the way municipalities interact with installers. In Gothenburg, the municipality directly interacts with installers through a role of customer. Municipally owned housing and utility corporations order energy retrofitting services from installers, but are challenged to realise climate ambitions due to the focus on the lowest purchasing price. In Rotterdam, utility and social housing provision is largely privatised. The municipality has a smaller and indirect role in the form of supporting installers training and innovation projects, although it can set more conditions to support installers.

Table 1: Contextual factors Gothenburg and Rotterdam

	Gothenburg	**Rotterdam**
Population	631.000 (municipality) Growing population till 700.000 inhabitants by 2035[8] 1,070,935 inhabitants (region, Gothenburg Business Region, 2023)[9] 1.772.190 (Västra Götaland County)	670.425 inhabitants (municipality) Growing population (in 2012 the city had 616.456 inhabitants); further growth expected till 733.012 inhabitants in 2040.[10] 2.390.101 (Metropole region Rotterdam-Den Haag, 2020)[11] 3.8 million (Province of South Holland)[12]
Geography and climate	- Coastal and river city - Hilly - More monocentric, with Gothenburg being the economic and political capital in the Västra Götaland County - Baltic climate with cold winters and mild summers	- Coastal and river city - Flat valley - Part of polycentric Randstad area - Maritime climate with mild winters and mild summers
Economic base	Maritime; Life science; Culture and creative industries; Automotive, logistics and mobility; ICT and space	Maritime IT & Tech Energy Life science and health Agri & Food Transport & Logistics Architecture Water management
	Shortage installers	Shortage installers
Social equity	Energy injustice, but no energy poverty	Energy poverty and increasing injustice
Energy and heating infrastructure and ownership	District heating since 1948; ambition to maintain 1,350 km length; 90% of the apartments connected	District heating since 1949; ambition to extend.

	Energy and heating generation and distribution by Göteborg Energi – municipal firm	Energy generation by private firms Energy grid operated by the public firm Stedin District heating network operated by private firms: Eneco in the north and Vattenfall in the South
Building stock and Ownership	Well isolated housing, largely built within the Million Housing programme (1964-1974)	Poorly isolated buildings, built in (post-)war period (1940's-1970): focus on speed and low-cost.
	Universal public housing, provided by municipal housing corporations within Framtiden Group	Social housing provided by private housing corporations
Sustainability transitions	- Increase energy- and heating efficiency - Transition to circular economy	- Natural gas phase-out: replace gas boilers by full electric or hybrid heat pumps (the latter combines gas with electric heating), district heating or other heating technologies - Increase energy- and heating efficiency - Transition to circular economy
Sustainability goals	- Climate neutral in 2030 - Overall climate in all projects by 90% in 2030 (baseline of 2020) - Share electricity from renewable energy sources in 2025: 100% - District heating from renewables and residual heat in 2025: 100% - Energy consumption reduction by at least 30% in 2030 (baseline 2010)	- 55% CO_2 reduction in 2030 (baseline of 1990). - Climate neutral in 2050 - Convert building stock from natural gas to fossil-free heating infrastructure: 263.000 buildings (of which 255.000 houses) of the total stock of 350.000 buildings

3. What is the role of installers in energy transitions and what challenges do they face?

Despite large differences between Gothenburg and Rotterdam in the urban contexts, policy goals and sustainability trajectories, the role of installers in the energy transitions and the challenges they face are largely similar. Installers in both cities have a direct and indirect role in energy transitions and wider journey towards net-zero cities. Firstly, the success of the energy transitions depends on *the quality of the installers' work as they implement the actual retrofitting measures*. Illustrative are the identified installation mistakes which could delay the transition or cause other negative effects (table 2).

Secondly, installers have a highly influential role on *advising customers* on which retrofitting measures (not) to take. Customers have limited knowledge on the complexity of installations and have a high trust in installers. Accordingly, they often follow the installers' advice. This advice is not limited to the purchasing decision of new installations, but also. on how to use these. This illustrates the effect installers have on the energy-performance of installations across the life cycle. They design, order and install installations and repair and maintain these.

Thirdly, at least in the case of Rotterdam, installers *affect inclusive energy transitions by taking into account the budget of their customers*. One the one hand, they may delay transitions by advising their customers against expensive retrofitting measures (e.g., a heat pump). On the other hand, they attempt to include customers with smaller budgets, for instance by providing installations against cost price or doing simple maintenance services for free. Large installers in Rotterdam make long term energy-retrofitting plans with social housing corporations to keep retrofitting affordable for low-income tenants.

Finally, the influential role of installers becomes clear from the *power installers have vis-a-vis upstream actors* due to the installers' access to customers and the dependency of manufacturers on the availability and quality of installers to install installations.

Table 2: Installation mistakes

Installation mistake	**Effects on energy transitions**
Heating installations with too much capacity for the size of a room	Energy efficiency losses Higher purchasing costs
New heating installations in poorly isolated houses	Energy efficiency losses
Installers ignore or forget fine-tuning of installations	Energy efficiency losses
Installers ignore flue gasses regulations in heating systems	Risk accidents

Installation mistakes with PV systems: wrong cables; open cables; wrong connectors; cables against sharp edges; too many PV panels for the capacity of the in-house fuse box; incorrectly placing of roof tiles after PV installation	High repairing costs Risk accidents
Installations at places that are hard to reach for maintenance and repair	Higher maintenance costs

Challenges

Installers in Gothenburg and Rotterdam share many similar interrelated challenges that negatively affect energy transitions:

- There is a *large shortage of skilled installers*. This is caused by historical and structural problems linked to an aging population and limited inflow due to an incorrect image of installers and their work. Increased customer demand for retrofitting measures during and after the energy crisis and strict policy goals have put further pressure on the labour market.
- The strongly increased demand and a *lack of certification and control* have increased the presence of so-called *'beunhazen'*, being cowboys who enter the market and who lack the willingness or skills to deliver a high quality. They negatively affect transitions by delivering a low quality and endangering the good reputation of other installers.
- Installers are *'invisible'* due to their small size, irregular place where they work and modest marketing skills. Accordingly, interaction with governments and research institutions is low. This hinders governments to support installers or to inform them about changing regulations or subsidies. Likewise, researchers do not get (enough) insights into the challenges installers face and how they react on new technologies or more environmentally friendly materials. This could hinder upscaling and fast deployment of new retrofitting measures and the transition to the circular economy by re-using materials.
- Installers face a *manufacturers' lock-in.* This hinders installers to become more circular and to speed up installation processes by combining modules from different manufacturers and to provide affordable solutions on a system level[1].
- Installers are confronted with *increasing technological complexity* due to the presence of different competing technologies (e.g., heat pumps, gas boilers, thermal heating), challenges to integrate different technologies (e.g., PV panels, hybrid heat pumps), and too fast development of the same technology (i.e., fast introduction of new models by manufacturers).
- A *'gap' between installers' strong technical (craftmanship) skills and relatively weak soft skills (communication and advise)* increases the risk on installation failures. This is especially the case when installers are confronted to provide advice on new

[1] The counter argument in favour of such a dependency on one or a few manufactures is a higher quality due to warrantee on the spare parts and less risks on mistakes related to the high complexity of installations by different brands.

technologies and the integration these with the higher technology layers of energy systems and the building envelope.
- Installers also have *limited capabilities (skills, funding and time) to reduce the overall environmental impact of installations and materials*.
- Installers are confronted with *reduced accessibility of cities*. Some large installers try to cope with these challenges and to reduce their carbon footprint by operating city hubs as depicted in box 1 (added in the appendix).

We have also identified two particular challenges for installers in Rotterdam:

- A *lack of space in buildings* to install alternatives for gas boilers, such as heat pumps. Such new installations are (still) too large for apartments and households may also *lack affordable access to district heating networks*.
- Installers are challenged by *irregularities in regulations and standards*, such as heat pumps as a new norm and implementation of zero-emission zones. These irregularities lower installers' incentives to invest in training and innovation, which on their, turn slow down energy transitions.

Finally, we have identified two similar wider transition challenges (i.e., beyond installers' challenges) in both cases:

- The *capacity of the electricity grid* and challenges to *maintain a secure and affordable heating and electricity supply*. Although, this can be perceived as an advantage for installers in the form of long-term maintenance and repair work on these urban infrastructures, it hinders energy transitions.
- A slow *development of certificates and the associated changes in the educational system.* That means the institutional changes that are required to facilitate training for installers to obtain a holistic understanding on energy-saving.

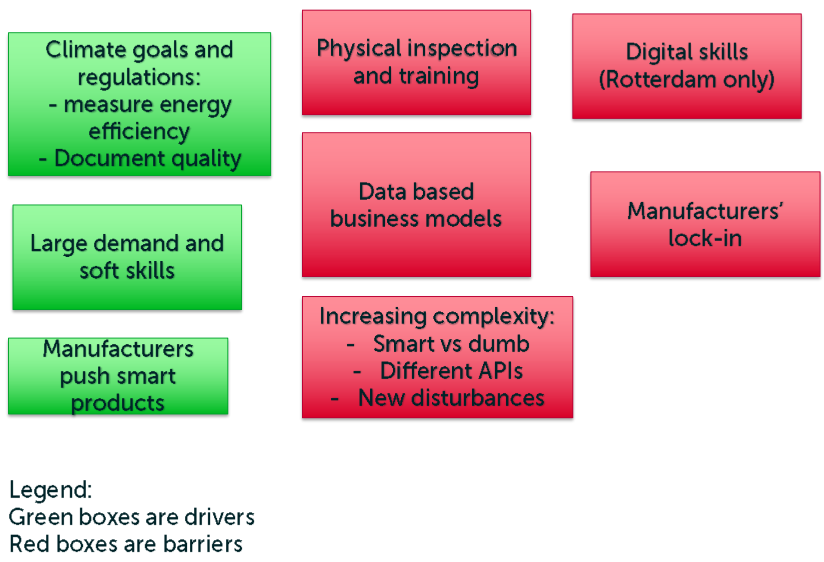
4. How does digitalisation affect installers and energy transitions? What are drivers and barriers of digitalisation?

Also, the results on digitalisation are largely similar across the cases. In both Gothenburg and Rotterdam, digitalisation is driven by market (increased demand), regulatory (mandatory use of registration and/or monitoring platforms) and technological dynamics (manufacturers push 'smart installations') within energy transitions. The increasing shortage of labour due to increased demand and stricter regulations drives deployment of administration, registration, monitoring and/or predictive maintenance platforms. These platforms can increase efficiency of installers across their activities. Moreover, challenges with soft skills can partly be overtaken by such platforms helping installers to interact with clients. For instance, platforms can provide standard templates helping installers to obtain customer data and to send invoices. In addition, national regulations following European directives in both cases oblige installers to use digital monitoring and reporting platforms. These platforms aim to document the quality of installers work, which materials they use, and to measure the energy-performance of buildings. Also, manufacturers increasingly develop smarter installations and systems. They partly provide these to support installers, for instance by installation apps, and partly to obtain data from their smart products to provide new services to installers or their customers. Overall, we observed deployment of platforms across nearly all installers' practices, also including training, input sourcing and maintenance.

However, our results also unveil limitations to digitalisation across all practices, such as the need to 'see and feel' physical installations during training and to obtain trust and contextual knowledge of customers during the inspection of the building and installations. Such physical visits are important to avoid installation mistakes. Likewise, in both cases installers use digital platforms to source their materials, but smaller installers in particular still visit wholesalers to get project advice. Furthermore, installers struggle to develop new data-based business models, such as through new types of predictive maintenance contracts (instead of an annual visit and repairs based on hours) or selling energy-saving advise instead of a device that provides heat or electricity. Finally, digitalisation could increase complexity for installers, such as the challenge to connect smart and dumb systems and installations with different APIs.

Figure 2 summarises the barriers and drivers of digitalisation and box 2 provides a small selection of platforms identified in our study that could be used by installers.

Figure 2: Drivers and barriers of digitalisation



Source: Own elaboration

5. What is the role of frugal innovation to overcome the largest challenges of installers? What are barriers and drivers of frugal innovation?

Regarding frugal innovation the results are similar across the cases as well. Frugal innovation is driven by the large scarcity of installers and the need for speed of transitions due to the large demand and urgent climate goals. Furthermore, installations are regarded as low-cost and functional products, limiting installers to use more environmentally-friendly materials and to raise their prices, especially for those installers who want to continue serving their low-income customers.

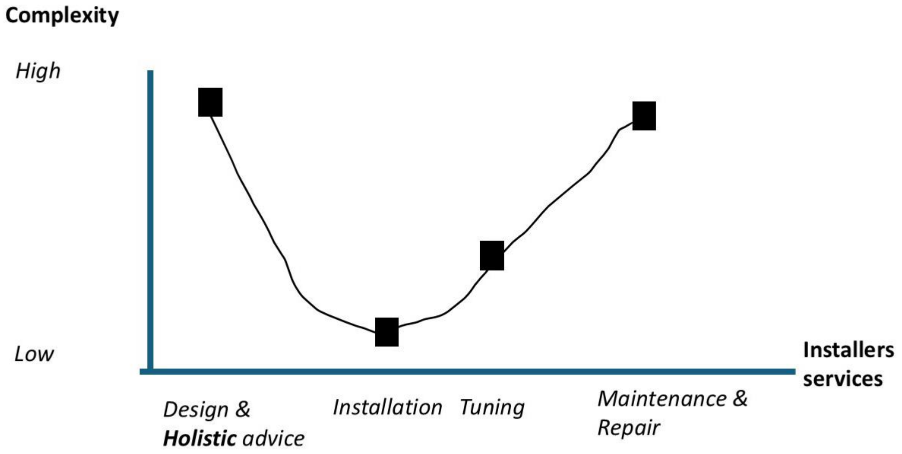
We have identified various frugal innovations developed by installers. For instance, the Breman 'collective portiekhybride' can be regarded as a frugal solution to overcome the space constraint of Dutch apartments and has a lower price than individual heat pumps (see box 3). Likewise, some installers take back old gas boilers and re-use these for customers who cannot afford a heat pump yet or wait until they get connected to a district heating networks. Another example is deployment of video calls through WhatsApp in which installers explain customers how to conduct basic maintenance and repair services, such as refilling a kettle. Installers conduct such services to avoid traveling too much (e.g., to be more efficient) and provide these services for free in exchange for a long-term loyalty from customers.

Also, other actors provide frugal innovations to cope with the challenges of installers or their customers. For example, de Beroepentuin reduces complexity of installers training in various dimensions (see box 4). Likewise, manufacturers develop apps that enable installers to tune heating installations more easily and quickly. Manufacturers have also developed relatively simple and affordable solar panels and heat pumps that end-users can install themselves through a plug-and-play system. Downside of these frugal versions of complex installations is that it might increase the chances on installation failures as end-users do not know how many installations can be connected.

We have identified the following barriers that hold back frugal innovations:

- The *large availability of funding* through customer demand and subsidies may lower the speed of installers: "they can do less for more".
- *High quality standards and the need to secure energy and heating supply* limit installers to innovate.
- *Standardisation is often hard to realise* due to existing legacy infrastructures, installers with own styles, and manufacturers lock-ins.
- *Digitalisation can increase complexity*, for instance, due to different smart installations (e.g., PV systems; heat pumps) with each a different API. Installers are challenged to connect these.
- The *complexity of installer services varies* (see Figure 3). Accordingly, 'frugal training' can help to quickly learn people to install devices, but design, tuning, maintenance and repairing services require a longer on-the-job learning trajectory.

Figure 3: Complexity of installers' services



Source: Own elaboration

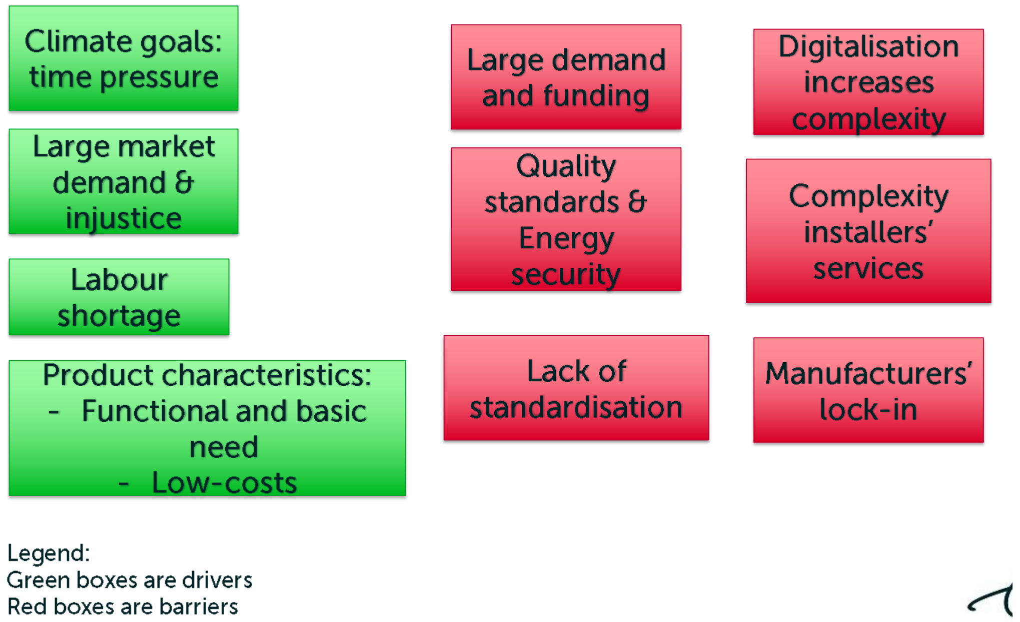
Table 3 shows the examples of frugal innovations, which include process and product frugal innovations. Figure 4 summarises the drivers and barriers of frugal innovation.

Table 3: Examples of frugal innovations

Frugal innovation	**Examples**
By installers	Breman 'collectieve portiekhybride' Installers take back old gas boilers and rent these out WhatsApp video calls for problem solving
For installers	Beroepentuin training concept Manufacturers provide apps to install and tune installations Simple and affordable versions of PV cells and heat pumps through a 'plug-and-play' logic

Source: Fieldwork

Figure 4: Drivers and barriers of frugal innovation



Source: Own elaboration

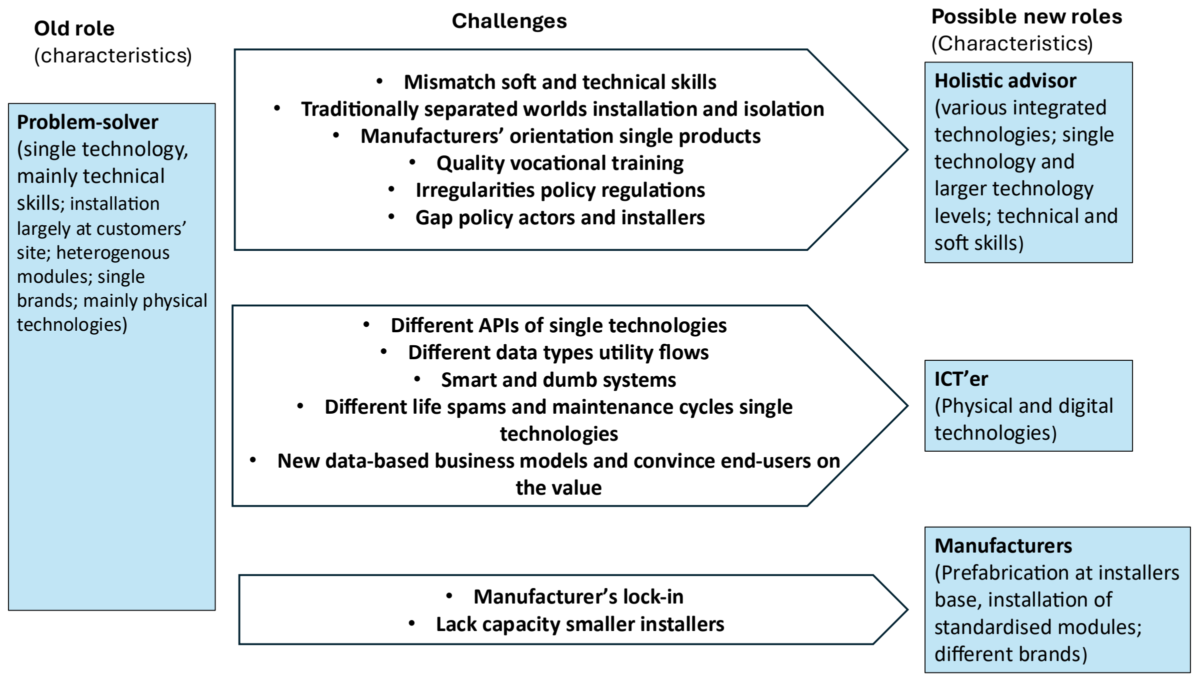
6. New potential roles of installers in energy transitions

Due to the challenges installers face (as discussed in the previous sections), we suggest that installers are in transition themselves. Thereto, we have identified the following *possible* new roles of installers (see figure 5):

- Installers may change from problem-solver and advisor around a single technology towards a *holistic advisor* on how to realise energy-efficiency by also taking into account larger technological systems and the building envelope. Challenges related to this shift include a further 'gap' between installers' craftmanship and soft skills hindering installers to provide this holistic advice. This challenge is even larger due to irregularities in governmental regulations and a gap between governmental actors and installers. This negatively affects installers abilities to provide proper and holistic advice. Other challenges hindering this transition encompass manufacturers' orientation towards a single product, and the quality of the vocational training infrastructure in both case studies that cannot keep pass with the societal need for holistic advice.
- Installers increasingly obtain a role as *ICT'ers*. Market, technological and regulatory dynamics 'oblige' installers to work on smart installations and utility infrastructures and to deploy all kinds of digital tool. This affects all installers' services (advising, installation, maintenance and repairing). However, also this shift is complex as installers are confronted with various technological integration challenges and new business models.

- *Installers as manufactures*. Large installers in our case on Rotterdam do not only start prefabrication and modular production to reduce installation time. They also use this new approach as a strategy to cope with the labour shortage by including workers in a safe 'manufacturing environment' that has less (or other) restrictions than a construction site or in peoples' home. However, a challenge of this strategy is a manufacturers' lock-in, reducing the options to quickly combine standard modules from different manufacturers.

Figure 5: Possible transitions of installers



Source: Own elaboration

7. Recommendations

We provide the following recommendations to Gothenburg, Rotterdam and other cities that want to support installers and to speed-up inclusive energy transitions.

Firstly, we recommend municipalities and higher governments to *use other criteria than only the lowest purchasing price in their tenders* when purchasing installation, repair and maintenance services of public buildings and utility infrastructures. These criteria should encompass a focus on energy efficiency, deployment of installations and materials with a low total environmental impact across the lifetime and provide budget and time for installers' (on-the-job) training and involvement in research programmes.

Secondly, municipalities should *link energy advisors with installers*. This stimulates cross-learning between advisors who have strong soft skills and installers with their craftsmanship.

It also helps to provide holistic advice and to implement projects to increase energy-efficiency. Moreover, through cooperation with installers, energy advisors get access to hard-to-reach communities who lack trust in authorities and new kinds of (public) advisors. Installers often already have a long-term trust-based relationship with such citizens. Municipalities can create this link by putting cooperation between installers and energy advisors as a condition in retrofit subsidies for firms and households or in public tenders aiming to reduce energy poverty through energy fixers.

Thirdly, we propose authorities to *link retrofitting subsidies to certificates* to increase the quality of installations and reduce 'beunhazen'. This already happens in other countries, such as in France.

Fourthly, we suggest *municipalities to cooperate with wholesalers* to reach small installers. This is a key place to inform installers about new (forthcoming) subsidies and regulations, and to obtain insights into the challenges installers perceive in implementing retrofitting measures. Municipalities can do this by participating in training programmes offered by wholesalers, the organisation of joint trade fairs or by simply being present at the wholesalers counter every now and then.

Fifthly, industry associations and municipalities can *jointly participate in major urban festivals*, such as the World Port Days in Rotterdam [13] in order to promote the sector among the general public. This would be beneficial with an eye to attract new (future) workers and to inform citizens about how to distinguish between good installers and beunhazen.

Sixthly, *research institutes* should not only *interact* with end-users, but also *with installers*. We particularly recommend involvement of installers in Living Labs. Installers are the actors advising end-users on new technologies, materials and retrofitting measures and implement these. So, taking installers on board in innovation pilots will increase the speed of innovation upscaling. This interaction can be stimulated by setting involvement of small installers as condition for innovation subsidies. Moreover, industry associations can organise excursions to Living Labs, where they can also provide workshops and learning sessions for their members. Finally, researchers can participate in trade fairs where they show their projects to installers and ask for feedback and involvement in new projects.

Seventhly, authorities should cooperate with vocational schools, installers and upstream actors to *develop new types of training.* This training should focus soft skills and understanding of the system perspective of the interactions between the building shell and installations aiming to realise energy-efficiency. Such training is already offered by the vocational school Heta Utbildningar (see box 5). Another dimension of training is educating installers about the total environmental impact of the materials and installations they use. The new training can be done by challenge-based assignments, internships and project-based education where students from different programmes (e.g., roofers, electricians and plumbers) jointly solve a 'retrofitting in the circular economy puzzle'.

Finally, municipalities should *support installers to overcome access problems in cities*. For instance, they can lower parking fees for installers, or give them permission to access car-free areas. Furthermore, municipalities can set up collective city hubs for small installers, providing them access to repair shops and electric bikes. In this way, also smaller installers can provide maintenance and small repair services in a more sustainable way. When these measures are linked to certification, municipalities can also increase the quality of installations.

8. Limitations and further research

Our study has the following limitations:

Firstly, our study is based on only two case studies based on in-depth interviews with a large diversity of actors, including different types of installers (e.g., small versus large). Accordingly, the results cannot be generalised. Therefore, we propose further research on installers in other cities and other types of installers (e.g., business-to-business installers working on industrial installation and in port infrastructures). Moreover, a large survey would complement our study.

Secondly, we mainly interviewed certificated installers who might be less frugal than beunhazen. Including beunhazen in a study would provide more insights in the role of frugal innovation in energy transition. This would help to provide detailed advise on how to deal with the balancing act between the speed and quality of transitions.

Finally, we conducted our fieldwork largely during a peak period when installers were extremely busy to fulfil large demand for retrofitting measures. This did not only restrict our access to installers, but also provided a biased view. Therefore, we suggest a longitudinal study in which we follow developments of installers over a longer time period.

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Appendix: Boxes

Box 1: Installers on bikes and city hubs

The Bravida Greenhub and Van Dorp City Solutions are similar innovative installation service concepts that has been piloted in Gothenburg and Rotterdam. Bravida and Van Dorp provide installation services from small hubs in a central location in Gothenburg and Rotterdam respectively. From these central hubs, installers travel by electric bike, electric mopeds, public transport or on foot to provide maintenance and repair services to their customers. They have also changed the flow of goods. Instead of having a separate truck ride to each customer for the delivery of an installation, the installers now collect installations at a location at the border of the city. From this location they deliver multiple customers within a single trip.

The installers have developed this solution to reduce their environmental footprint and to overcome access problems in cities caused by traffic jams, reduction of parking space, increasing parking costs and bans of diesel and other high-emission car types in city areas. An indicator of success is that the hub concept has been scaled to the other cities of Stockholm (Bravida) and The Hague and Amsterdam (Van Dorp).

Box 2: Digital platforms

Current is a local energy management system through a device that is installed in a fuse box. This local rather than cloud-based solution offers cybersecurity and avoids hackers to enter and disrupt energy management systems. It is a brand-independent system and can connect different manufacturers and a variety of products including batteries, PV panels, electric vehicle chargers, inventers, thermostats, heating boilers, heat pumps and smart meters. It overcomes challenges of different IT protocols and can collect different types of data (e.g., temperature in the fuse box; grid frequency; electricity usage) helping users (consumers and business) to manage energy with an eye of energy saving and avoidance of electricity grid congestion. The device can be installed easily with a navigator. Currentt tries to safeguard quality by working with qualified installers.

FYXN is a consumer-oriented platform to search and compare installers. Its initial focus was on PV installers as the owners have a deep knowledge and networks in this business due to their past positions in this industry. The company has extended to other businesses, including heat pumps, charging poles, isolation and home batteries. What differentiates FYXN from other platforms is the combination of being independent (e.g., it is not part of a manufacturer or energy utility) and a focus on quality. The quality is realised by working with curated installers (based on certificates and/or past experiences) only, an open knowledge database with information of different dimensions of installations (e.g., available brands; parts needed; functioning of installations; possibilities for funding) and post-installation control by FYXN.

Insmart is a brand-independent predictive maintenance platform for gas boiler installers. The platform works through a sim card in a module that is installed in boilers. This sim card is connected to a GSM (rather an than internet) network to safeguard a stable and reliable connection, also in places like cellars. The platform provides installers an increased efficiency by sending notifications when service and maintenance is required. This reduces the number of customer visits and helps installers to bring the right materials for each visit.

Kiona is a smart building platform that enables building owners to monitor different utility systems (i.e., installations), including water, heating and energy. It is based on open-source technology, enabling building owners to connect different system protocols (e.g., from different manufactures) and to integrate third-party software. The platform provides building owners solutions to increase energy efficiency, automation and reporting. As it connects central managers with local facility managers and installers it provides a faster response to interruptions in utility systems.

WhatsApp is widely used by installers. They receive pictures from customers giving a first rough impression about installations. Likewise, they share pictures with colleagues and wholesalers for advice and to learn about new installations. Furthermore, they use the video call function to support customers with problem-solving. Through this support on distance, installers help customers to do basic services by themselves, such as refilling the kettle of a gas boiler.

Box 3: Breman 'collectieve portiekhybride': a frugal innovation for phasing-out gas boilers in social apartments

The Breman collective hybrid heat pump for apartment buildings (in Dutch: 'portiekhybride') was developed by installer Breman and heat pump manufacturer Itho Daalderop as a response to an innovation challenge by the social housing corporation Woonstad Rotterdam in 2019. Woonstad's request was an affordable solution to reduce CO_2 emissions for its existing apartment buildings with low disturbance for inhabitants during renovation work, and a maximum budget of €15.000, - per house.

The winning collective hybrid consists of the following dimensions:

* The collective heat pump is installed on the roof of the building and connected through the chimney to the existing heating boilers of four households. This means usage of existing infrastructure. Moreover, the collective roof top heat pump rather than individual ones for each household lowers the price of the heat pump and overcomes the space constraint of small apartments where heat pumps do not fit.

* Disturbance of households is limited as the renovation work in apartments is limited to an installation kit and replacement of radiators and ventilation boxes.

* The hybrid heat pump reduces natural gas consumption and CO_2 emissions. The air source heat pump enables CO2 reduction with maximum 65%.

* The rooftop collective can be extended with PV panels, hence further reducing the electricity costs of households.

* The collective hybrid system can easily be adapted to a full electric system in a later stage by removing the gas boiler.

* The system is largely based on standardised prefab modules; 80% of the installation- and production work is done outside the construction place. This prefab strategy reduces the number of installers and

speeds up installation time. It also enables less installers working on the roof. So, it requires less installers who need a certificate for this type of work on roofs.

Many of these dimensions already exist. However, the smart combination of them makes this a best practice of a frugal innovation that tackles the various challenges of Woonstad, installers and energy transitions. The collective hybrid was successfully tested in seven apartment buildings in 2021 and is ready to be upscaled. However, the exception of apartments (and monuments) to the mandatory shift to (hybrid) heat pumps has reduced the need for such innovations.

Box 4: Beroepentuin, a pioneering frugal training model

Beroepentuin was formally founded in 2018 with the mission to provide excluded citizens 'the shortest trajectory to a paid job', realised by a short practice-oriented training. Initially, it covered various industries including healthcare, logistics and installers. However, this broad approach was too difficult to 'sell' to firms who need labour and public subsidy providers like municipalities and the Dutch State.

The existing model works as follows. It focuses on jobs in energy transitions (including installers) but has kept its original mission and core business of training of various types of citizens with a distance to the labour market. These include former prisoners, migrants, long-term unemployed persons, women and youths with social problems (e.g., school drop-outs).

After an intake aiming to find the most appreciate job, participants start a training in a 'safe environment' in the form of a physical simulation centre in a large hall (and not on a construction site) where participants work in and around a model house by practicing all kinds of installers work, such as installing solar panels, charging poles or basic electrician work. The safe environment is further enabled by experienced coaches who work for partner firms, but who have experience of being excluded in the past. This latter is crucial to gain trust as the coaches have had similar personal problems (e.g., being in prison or unemployed for a long period) and can help to overcome barriers, such as being on the on time on the workplace (which is far from straight forward for persons who were excluded) or how to deal with issues like being a minority in a group.

Beyond this safe environment Beroepentuin uses various frugal solutions to keep its cost low and to make training more accessible for participants who do not fit into formal education programmes either by language barriers or by other learning problems:

*Usage of *pictures* (rather than text) explaining the basic equipment installers use for a certain profession.

**Short and simple manuals* with an overview of the most important words (about 500) belonging to a certain profession. These manuals are developed in cooperation with Techniekcollege Rotterdam (a vocational school) and Sociaal Economsiche Raad (an advisory board for the State on social-economic development).

**Reverse learning*: participants have the option to join formal education afterwards; i.e., it starts with practice and participants can do theory afterwards.

**Usage of equipment* (e.g., solar panels, gas pipes, insulation material) *and trainers from partner companies.* These workers are (temporary) not able to their normal job, for instance due to physical problems like having a backache, but they are able and willing to coach participants.

**Making installations visible in physical demonstration models*. Examples include electricity systems in a house or district heating pipes. In this way, participants can directly see how different individual parts work and are connected to each other. Thus, the system perspective is visible, and participants can directly practice installing and connecting the different parts in the demonstration model.

After the training, participants start working for a partner firm. The partner firms - including construction firms, installers and utility firms - contribute for about fifty-percent of the income, whereas the other half comes from public subsidies.

The model seems to work well as evidenced that the firm has scaled to other locations in The Netherlands.

Sources: Fieldwork & [15]

Box 1: Heta Utbildningar: a holistic heat pump installers training

Heta Utbildningar is a training centre for heating installers in the city of Härnösand in mid-Sweden. It offers vocational training programmes for different types of installers, such as plumbers, PV installers, and heating installars. In addition, it offers individual courses for professionals on specific themes, like working with F-gasses.

What differentiates this training centre from other vocational and professional training schools in Sweden is that it (still) the only examination and certification centre for heat pump installers. The training to obtain this certificate is a new programme that goes beyond heat pump technology and also details its functioning in the heating system and building shell. With this extended knowledge, heat pump installers do not only sell a technology providing heat and warm water, but they can also provide the right advise on how to improve energy efficiency. The training can be done at other schools, on the job and partly online. However, examination is still only done in Härnösand.

The current certificates are still concepts as the formal certification system is still in development. Development of this system is led by the Swedish Energy Agency. This agency, Heta Utbildningar and other actors such as accreditation bodies work on all dimensions needed for such a certification system, including new course manuals; other training materials; exams; accreditation criteria, etc. Once the system is in place, the certification scheme and experiences obtained in Härnösand will be rolled out across the country.