



**Gemeente  
Amsterdam**



## **Solar Panel Reuse Chain for Social and Environmental Impact**

Interim report Carbon Neutral City Alliance (CNCA) Fund 11/07/2025

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# Executive Summary

Amsterdam’s solar panel reuse chain, supported by the CNCA Gamechanger Fund, is a collaborative effort initiated and pre-financed by the Municipality of Amsterdam. It rescues still-functional PV modules from premature disposal to extend their lifespan, reduce CO<sub>2</sub> emissions, and ease energy poverty – at no upfront cost to households, substantially lowering their energy bills. Through a coordinated chain for sorting, testing, certifying, and packaging, certified second-hand panels can be redeployed in underserved communities, helping to advance a more inclusive and circular energy transition.

Since the start of this year, our reuse chain partners have processed 2 040 panels, of which 707 have already been reinstalled – including five balcony-mounted systems in Amsterdam West equipped with real-time monitoring devices. The re-deployment of these panels is estimated to avoid 278–347 tonnes of CO<sub>2</sub>-equivalent emissions, corresponding to over €140 000 in avoided shadow costs. In the Hoptille neighbourhood in Amsterdam Southeast, 104 households have been invited to participate; installations of four panels per home will begin once participation is confirmed.

KPI	Description / Measurement	Status June 2025	Target end 2025
1.1	Input of solar panels in reuse chain	2,040	4,000
1.2	Throughput of solar panels in reuse chain	707	2,000
2.1	Saved emissions (projected kg CO <sub>2</sub> -Eq)	278,000-347,000	789,000-983,000
2.2	Saved shadow costs (projected Euros)	142,000-178,000	401,000-503,000
3.1	Households supported in Amsterdam	5	200
3.2	Solar panels households Amsterdam	15	800
4	Social work in reuse chain (hrs)	1,163	2,280
5	Knowledge dissemination, replicability	Annual review included in final report	

Table 1: Overview interim project results solar reuse chain

In parallel, researchers from Leiden University and AMS Institute will closely monitor system performance of these pilot projects and conduct resident interviews to validate environmental and economic outcomes. This collaboration will accurately quantify cost savings and capture tenant experiences, ensuring that our conclusions rest on robust empirical evidence.

As part of our continuous improvement efforts, we are committed to enhancing the reuse chain with streamlined logistics to bolster the financial viability of second-hand PV systems in the long term. By year’s end, we anticipate processing around 4 000 panels – now equivalent to roughly 1.2 full-time social-employment positions. We are exploring with our chain partners how other equipment, such as mounting frames and inverters can be included in the chain to improve cost-effectiveness.

Next steps include completing the installations in Hoptille, evaluating the impact of the current pilots, scaling up the balcony projects, initiating new pilot initiatives, and strengthening collaborations across the city. The final CNCA report will compile all findings, lessons learned, and practical recommendations for replication – helping to lay the groundwork for an inclusive and circular energy transition.

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# 1 Introduction

The Solar Panel Reuse Chain project addresses the alarming trend of prematurely discarding fully functional photovoltaic (PV) modules. In collaboration with local experts in collection, refurbishment, testing, and certification, we are building a fully integrated reuse chain. Our goal is to recover 4,000 solar panels in 2025, with at least 2,000 reinstalled that same year. By the end of 2026, we aim to have supported 800 households in Amsterdam residential complexes affected by energy poverty.

Thanks to support from the CNCA-USDN fund, the City of Amsterdam will launch several pilot projects in 2025. These will take place in neighborhoods where local renewable energy generation is most needed and where reuse offers the greatest value. Through these pilots, we aim to demonstrate the societal impact of reusing PV-systems and to generate practical insights for scaling and replication.

This approach not only diverts valuable materials such as silver, silicon, and indium from the waste stream and reduces CO<sub>2</sub> emissions, but also delivers clear social benefits. Households facing energy poverty will see reduced energy bills, while local social enterprises create employment opportunities for people distanced from the labor market.

Fully aligned with Amsterdam's Roadmap to Climate Neutrality 2050 and its principle of "unequal investment for equal opportunity," this initiative offers a human-centered, circular solution – one that redefines project success beyond financial returns alone.

## 2 Background Information

### 2.1 Premature solar panel disposal: a growing challenge

TU Delft, Leiden University and AMS Institute, recently investigated the value of lifetime extension strategies for solar panels (de Vilder et al., 2024). The study highlighted the significant environmental impact of premature panel replacement, identifying alarming cases where solar panels were discarded well before reaching their technical end of life. This growing trend is driven by three key factors:

1. Historically low panel prices, particularly for imports from China;
2. Rapid performance gains in new panels compared to those installed 10 years ago;
3. The fact that panels account for only a small fraction of total system costs.

As a result, when the business case for a system is reassessed, often triggered by the need to replace components like inverters, replacing the entire system, including still-functioning panels, becomes economically attractive. Many housing associations base procurement decisions on the lowest upfront price, which frequently leads to the use of a low-cost balance-of-system. Performance issues often arise at an early stage, and clients return to installers or ESCOs (WOCO-Zon – Circular Economy Lab 2024, personal communication). At that point, the costs of diagnosis and partial repair often outweigh the perceived benefits of a full system upgrade with higher generation capacity.

Stichting ZonNext, which facilitates the matching of supply and demand for second-hand solar panels, recently shared a striking example: a housing corporation replaced 19,000 panels (290 Wp, just 6 years old) after upgrading their monitoring system hardware. Similar practices occur in the utility-scale sector, where large solar parks are frequently repowered even when panels remain functional (Stichting ZonNext, personal communication).

Discarded panels are typically exported and downcycled abroad. Current recycling methods recover only low-value materials, while the most valuable components, like solar cells, are crushed and lost, ending up in concrete or asphalt (de Vilder et al., 2024). There is no industrial-scale, high-quality recycling process available today for recovering solar-grade materials. Due to technical and economic constraints, it may take many years before such methods become scalable, cost-effective, and sustainable (Späth et al., 2022).

## 2.2 A reuse chain for saving still functional solar panels

**Collection of second-life materials:** since discarded solar panels are treated as e-waste under the WEEE Directive, manufacturers pay an EPR fee for end-of-life handling. Today's collection network doesn't stimulate reuse. WEEE Nederland (handling >20% of national e-waste) is now trying to establish a dedicated collection stream that keeps cables intact and components undamaged, so discarded equipment can re-enter the second-life market.

**Matching supply and demand:** since 2021, Stichting ZonNext has matched used-panel supply with demand for affordable, second-life PV systems. However, complex logistics, panel-spec matching, inventory audits and multi-stakeholder coordination made reuse projects very impractical. By establishing a reuse chain with a buffered stock of certified, ready-to-install panels, ZonNext now eliminates that uncertainty and fast-tracks proposals and installations. **Figure 2** illustrates this chain, enabled in 2024 by a pre-investment from the City of Amsterdam.

**Regional reuse centers:** the WEEELABEX-accredited facility RSC Amsterdam is part of this reuse chain, and sorts discarded solar materials and stores second-life panels, certified at the national solar-PV refurbishment center. All operations are performed by staff with reduced labour-market access, employed via Milieuwerk (PSO Level 3).

**Testing and refurbishment:** intact panels from the regional sorting center are sent to Refurn B.V. in Apeldoorn for cleaning, micro-crack inspection and power-output testing. Each unit leaves with a traceable test report and is stored back at a regional reuse center. Refurn is also PSO Level 3 certified and employs people in vulnerable labour-market positions.

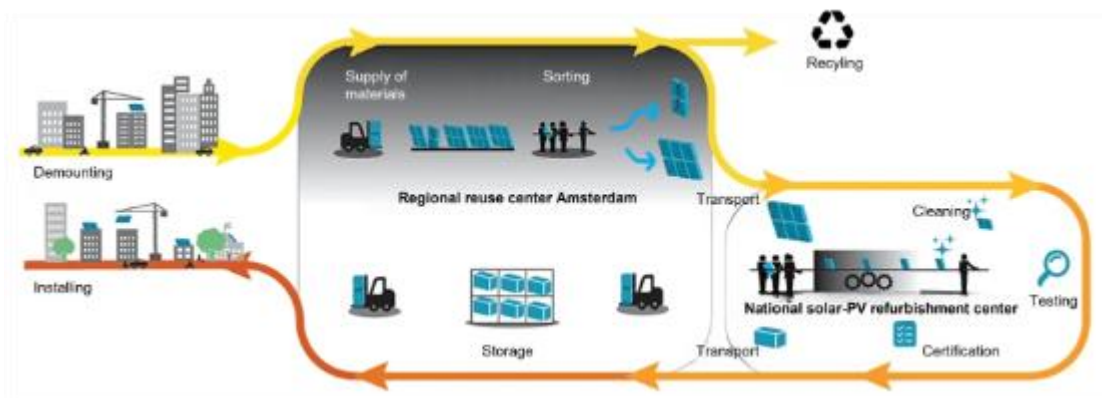


Figure 1: material and process flow diagram of the regional reuse chain for PV-systems

### **2.3 Limited demand due to lack of scale and missing financial incentives**

The reuse chain enables reliable collection, testing, and storage of certified, well-functioning solar panels. De Vilder et al. (2024) highlight the environmental and social benefits of reusing PV-systems. However, in today's market, second-hand solar panels offer little to no cost advantage over new ones, removing the financial incentive for reuse.

By scaling the solar panel reuse chain and offering complete PV systems – mounting structures and refurbished inverters – can significantly reduce operational costs and strengthen the business case for second-hand solar. The City of Amsterdam is currently working with reuse chain partners to optimize and scale up the existing regional chain. In parallel, we are preparing a European funding proposal with international partners to expand this model across borders under the working title Solar Reuse Europe. For more information, please contact: [.sloet@amsterdam.nl](mailto:.sloet@amsterdam.nl).

In the meantime, the City of Amsterdam is making use of the chain by deploying second-hand PV-systems in the city, where they are most needed.

### **2.4 Thousands of households left behind in the energy transition**

According to a recent study by TNO, approximately 400,000 households in the Netherlands experience energy poverty (Mulder et al., 2024). These households have low incomes combined with high energy costs or live in homes with poor energy performance. The average energy poverty gap per affected household amounts to €472 per year (Mulder et al., 2024).

According to the Amsterdam Federation of Housing Corporations (AFWC), as of the end of 2023, housing corporations in Amsterdam still owned approximately 29,000 homes with poor energy labels (AT5, 2024). In 2023, 1,977 homes were renovated at a high investment level of over €25,000 per unit (AFWC, 2024). While the housing corporations have now committed to renovating 2,500 homes annually in Amsterdam, they face growing and entrenched barriers that make meeting these targets increasingly challenging (AT5, 2024)

Deep renovation of multi-unit buildings legally requires approval from at least 70% of tenants or owners, often delaying projects for years (Verhoeven & Visscher, 2023). Financially, the “woonlastenneutraliteit” principle limits rent increases after energy upgrades, making it hard to recoup costly retrofit investments (European Environmental Agency, 2023). Meanwhile, government targets to build 100,000 homes annually (of which 30% social housing) strain housing corporations' capacity and budgets. Additionally, complex planning, subsidy processes, tenant engagement, and onsite disruptions create a high operational burden, further slowing renovations (European Environment Agency, 2021). Meanwhile, thousands of households in Amsterdam face rising energy bills without the financial means or decision-making power to invest in renewable solutions like solar panels or heat pumps.

## 2.5 Second-life solar panels: a bridge to an inclusive energy transition

Given these barriers, the temporary deployment of second-life solar panels on rooftops or balconies offers a practical bridge solution. It provides immediate energy savings and bill relief for households facing rising energy costs, without the delays, tenant consent procedures, or high upfront investments required for deep renovations. It also enables effective lifetime extension of solar materials at places where they are most needed and can optionally be upgraded and recycled once deep renovation takes place. This is a novel synergy approach for a circular economy and a social and inclusive energy transition. With this project, the City of Amsterdam contributes to the following policy goals:

1. **Energy Transition and Climate Goals:** We provide a solution for the effective use of temporary rooftops and offer opportunities to accelerate the energy transition for housing associations. By promoting reuse, we reduce the hidden carbon footprint of our city.
2. **Circularity:** We contribute to Amsterdam's circular objectives through the highest R-strategies. We preserve critical materials that would otherwise end up in low-grade waste streams.
3. **Sustainable Economic Recovery:** We create employment opportunities, offering new prospects for existing retraining programs, and combating energy poverty.
4. **Unequal Investment for Equal Opportunities:** We invest in broad prosperity through an area-based approach targeting vulnerable groups.
5. **Cooperative Initiatives and Local Ownership:** Reuse projects create new opportunities for collaboration with local energy cooperatives.

## 2.6 CNCA Gamechanger Fund: pilots for scalable impact

This project, supported by the CNCA Gamechanger Fund, is part of a broader effort to rescue discarded but still functional solar panels. What sets it apart is its strong focus on ensuring an inclusive energy transition. In 2025 - 2026, the City of Amsterdam aims to support 800 - 1,000 households that are struggling with high energy costs (Gemeente Amsterdam, 2024). The Gamechanger Fund will be used to cover installation costs of the first pilot projects and enable the preparation of detailed reports to share our methodology and principal findings. The pilot projects will generate practical insights and validate the impact of the approach, supported by active monitoring and evaluation in collaboration with AMS Institute and CML Leiden.

### 3 Approach pilot projects

Based on an initial exploration, we have designed a systemic workflow for repurposing solar panels to combat energy poverty in Amsterdam. In the final report, we will share key learnings for each step, drawn from the execution of our CNCA-funded reuse projects.

#### 1. Inventory & Agreements



- Leverage existing energy projects and networks to identify target buildings
- Assess roof or balcony suitability and resident profile against target criteria
- Establish project plan with building owner (in most cases a housing association)

#### 2. Implementation & Communication



- Inform individual residents on project details. Request their consent for installation
- Arrange installation with installer, pre-selected by municipality or building owner
- Loan out certified materials reserved in advance from the reuse chain. Retrieve materials to the chain once dismantled.

#### 3. Monitoring & Evaluation



- Monitor system performance and energy consumption data
- Advise households on flexible electricity consumption
- Assess impact through system modelling and stakeholder interviews with research partners

### 3.1 Inventory & Agreements

- To scale our initiative and connect to existing programmes, we will partner with on-the-ground organizations such as Stichting WOON!, which already identify retrofit opportunities, assess building conditions, and engage directly with households. These partners offer tailored advice and implement low-cost interventions, such as weather-stripping. Our goal is to integrate second-hand PV installations into a broader set of renovation measures, maximizing immediate impact without hindering long-term retrofit plans.
- To find our first pilot projects, we engaged our local stakeholder network to identify residential complexes that meet four key criteria: (1) **Low energy performance** (EFG rating); (2) **no confirmed renovation plans by the building owner** for the next five years; (3) **high incidence of energy poverty** ( $\geq 10$  % of household income spent on energy, per Amsterdam's definition); (4) installation of solar panels is **technically possible and feasible** on building(s). At this stage, we consider these initial guidelines rather than strict requirements, allowing room to learn and adapt through our pilot projects.
- Once a residential complex has been identified and the building owner agrees to proceed, formal agreements must be established prior to implementation. These should outline key elements such as material ownership and usage rights, cost-sharing arrangements, resident communication protocols, and responsibilities for operation and maintenance (O&M). A first agreement on material ownership and usage has been concluded with a building owner in one of our pilot projects (Hoptille); a template is included in **Appendix A**.

### 3.2 Implementation and Communication

- Once clear agreements have been made with the building owner, we proceed with informing households on the option to make use of a PV-system for free. They can sign up and provide consent for the installation and system monitoring. We have already reached out to residents in one neighbourhood. A template of the letter can be found in **Appendix B**.
- Once an agreement is made with the households, an O&M party, typically an ESCO or installer already contracted by the building owner/housing association, proceeds with the installations.
- All second-hand materials have been certified, pre-selected, and are ready for transport via the reuse chain. The installer coordinates the delivery with Stichting ZonNext, the reuse chain coordinator. Any additional materials are supplied by the installer. A key aspect of this project is that the municipality retains ownership of the materials. This prevents unforeseen tax liabilities for households and ensures that, after use, the materials return to the reuse chain for potential reuse or recycling.

### 3.3 Monitoring and Communication

- The operations and maintenance (O&M) partner monitors system performance and household energy use to ensure the PV installation delivers a clear benefit. If future changes (such as high feed-in tariffs) undermine the system's effectiveness, its impact will be reassessed. Households bear no financial risk in this project: both the system and related services are provided free of charge, with no additional costs passed on to residents. Under no circumstances should the PV system lead to higher energy bills.
- Households are advised by the housing association and/or energy service provider on their energy use to maximize their benefits of the PV-system and reduce their energy bills.
- AMS Institute and CML Leiden make an agreement with the O&M parties the first pilot projects to use the system and energy use data to assess the impact of the installations. Furthermore, the researchers will plan an interview with several households as part of their qualitative analyses.

### 3.4 Scientific research

Leiden University and AMS Institute are investigating the ecological and social impacts of solar panel reuse, with a focus on applications in social housing, as part of the [Circular Collaboration](#) (CirCol) research project. While the ecological impact is addressed in a paper currently under review, the social dimension will be explored in the upcoming pilot projects.

Social impacts remain underrepresented in circular economy literature, limiting the full valuation of circular strategies (Clube & Tennant, 2023). This research addresses that gap by using the Sustainable Business Model Canvas (Bocken et al., 2018; Bocken & Ritala, 2022) and stakeholder mapping to analyse how the reuse chain creates and captures ecological, social, and economic value.

Stakeholders will be classified according to the Social LCA guidelines (UNEP, 2020). Key representatives will be interviewed to identify relevant impact subcategories and indicators. Interviews will be coded inductively to capture both existing and emerging social impact categories.

For households experiencing energy poverty, quantifiable indicators will include reductions in electricity consumption (kWh), energy bills (€), and the share of income spent on energy (%). Qualitative insights will be gathered through interviews with residents.

Key findings will be included in the final CNCA project report, with references to any related (scientific) publications. For further information about this research, please contact [d.b.k.de.zilva@cml.leidenuniv.nl](mailto:d.b.k.de.zilva@cml.leidenuniv.nl) or [sietse.devilder@ams-institute.org](mailto:sietse.devilder@ams-institute.org).

## 4 Interim Project Results June 2025

KPI	Description / Measurement	Status June 2025	Target end 2025
1.1	Input of solar panels in reuse chain	2,040	4,000
1.2	Throughput of solar panels in reuse chain	707	2,000
2.1	Saved emissions (projected kg CO <sub>2</sub> -Eq)	278,000-347,000	789,000-983,000
2.2	Saved shadow costs (projected Euros)	142,000-178,000	401,000-503,000
3.1	Households supported in Amsterdam	5	200
3.2	Solar panels households Amsterdam	15	800
4	Social work in reuse chain (hrs)	1,163	2,280
5	Knowledge dissemination, replicability	Annual review included in final report	

Table 2: Overview interim project results solar reuse chain

### 4.1 KPI 1: Solar panels processed in reuse chain

By June 2025, a total of 2,040 panels have been sorted, tested, certified, and stored for reuse at RSC Amsterdam. Of these, 707 panels have already been reinstalled at various locations across the Netherlands. To ensure efficient throughput and maximize the number of panels being reused, we have agreed with our reuse chain partners not to restrict the use of panels originally reserved by the City of Amsterdam to install within the city. However, Stichting ZonNext will ensure availability of similar solar panels once new installations are scheduled for reuse projects in Amsterdam.



Figure 2: Site-visit of reuse chain partners at RSC Amsterdam

### 4.2 KPI 2: Environmental Impact

A case study life cycle assessment was conducted based on an upcoming pilot project in Hoptille (Amsterdam Southeast). Details on the case study can be found in **Appendix C.1**. **Table 3** presents the results for a single household (4 panels) and for 500 households (2000 panels) under two scenarios: a fossil-free electricity mix by 2040 and by 2045. The assumed timeline for decarbonizing the electricity grid significantly affects the projected avoided emissions. Further details on the avoided emissions calculations are provided in **Appendix C.2**.

	4 panels (FF 2040)	2000 panels (FF 2040)	4 panels (FF 2045)	2000 panels (FF 2045)	Unit
Emissions	147	73,500	147	73,500	kg CO <sub>2</sub> -Eq
Avoided	-1,725	-862,500	-2,113	-1,056,500	kg CO <sub>2</sub> -Eq
<b>TOTAL</b>	<b>-1,578</b>	<b>-789,000</b>	<b>-1,965</b>	<b>-982,500</b>	<b>kg CO<sub>2</sub>-Eq</b>
Shadow costs	66	33,000	66	33,000	€
Avoided	-867	-433,500	-1,071	-535,500	€
<b>TOTAL</b>	<b>-801</b>	<b>-400,500</b>	<b>-1,005</b>	<b>-502,500</b>	<b>€</b>

Table 3: Estimated CO<sub>2</sub>-savings for re-installed solar panels

In the case study, four 320 Wattpeak second-hand solar panels are installed per household, using refurbished mounting systems and a new inverter. We assume the system will operate for an additional ten years on average, after which all components will be fully recycled. Emissions are generated through the manufacturing, transport, and use of the inverter, as well as end-of-life processes. Details on these induced emissions are provided in **Appendix C.3**. The total carbon balance is calculated as the sum of induced emissions (shown in red) and avoided emissions (shown in green).

Based on our analysis, we estimate that each household equipped with four reused solar panels can achieve net savings of approximately **1,580 to 1,970 kg CO<sub>2</sub>-equivalent emissions** over a 10-year system lifetime. This corresponds to **€800 to €1,000** in avoided shadow costs, based on the CO<sub>2</sub> price adopted by the Municipality of Amsterdam.

Scaling this up to **500 households** (equivalent to **2,000 solar panels**) results in an estimated total savings of **789 to 983 tons of CO<sub>2</sub>-equivalent emissions**, or **€401,000 to €503,000** in avoided shadow costs. This aligns with our target for the number of reused panels to be installed through the reuse chain by the end of this year.

To date, **707** panels – tested and remarketed through the reuse chain – have been reinstalled, yielding an estimated **278–347 tCO<sub>2</sub>-eq** savings, or **€142,000–€178,000** in avoided shadow costs.

In both pilot projects, described in the following paragraph, we will monitor system performance to more accurately assess the environmental impact of each case. Additionally, the outcomes of this analysis will be compared with research conducted by Leiden University and AMS Institute to verify the results.

### 4.3 KPI 3: Social Equity Benefits in Underserved Communities

As of June 2025, the City of Amsterdam has agreed to launch two pilot projects in Amsterdam West and South-East, scheduled for installation in Q3 2025. Additional pilot projects are in development and will be presented in the final report.

#### **Balkoncentrale – An Untapped Potential in Amsterdam**

Five households in Amsterdam West have already been equipped with second-hand solar panels on their balconies (15 solar panels in total). These pilot installations were initiated by **De Energiewending**, a local energy advice service. Materials and installation costs were offered by the City of Amsterdam. Based on these pilots, the installers will develop a standardized installation protocol that ensures safety and can be used for replicability across the city. This protocol will be shared with the CNCA network in the final report.



Figure 3: Opening of the first Balkoncentrale in Amsterdam West. Source: Het Parool, Photo by Sil Moison

The Balkoncentrale is already a widely adopted concept in Germany, where over half a million such systems were installed in a single year (Utopia, 2025). In the Netherlands this remains a relatively new concept (Solarmagazine, 2024). We are currently mapping residential complexes in Amsterdam Southeast that are suitable for a similar approach. Our goal is to replicate the pilots and integrate the Balkoncentrale into the services offered by local energy advisers, using solar panels sourced from the reuse chain.

The Balkoncentrales demonstrate the potential of second-hand solar panels, particularly because the older panel size (1.00 x 1.70 m) is often more suitable for balcony installations

than the newer standard size (1.10 x 1.90 m). Additionally, the older design – less reminiscent of a flatscreen TV – may be visually more appealing on balconies, although this is, of course, subjective.

Each household equipped with a Balkoncentrale also receives a HomeWizard device, which provides real-time insight into their energy production and consumption. This increases awareness of electricity use throughout the day and enables residents to better align the operation of energy-intensive appliances with the solar power generated by their system.

### **Hoptille – Confronting Energy Poverty in Amsterdam Southeast**

The City of Amsterdam and housing corporation **Ymere** have reached a collaboration agreement to install second-hand solar panels on homes in Hoptille, a residential complex in Amsterdam Southeast. The area consists largely of single-family homes with a high incidence of energy poverty. The municipality will offer the solar panels free of charge through the reuse chain and cover the installation costs. Ymere will coordinate installation and maintenance with its energy service company, Norm. The energy benefits will go directly to the tenants. The municipality retains ownership of the materials. This prevents unforeseen tax liabilities for households. A template of the loan agreement is included in **Appendix A**.



Figure 4: In the Hoptille neighbourhood, the homes on the left are designated to be equipped with solar panels.

After having established a project plan with the housing corporation Ymere and energy service company Norm, **104 households have been invited** to attend a community information evening and have received a formal invitation letter to enroll in the project. A template of this letter is included in **Appendix B**. We are currently awaiting confirmation of the number of participating households. The results of this pilot will be presented in the **final CNCA report**.

## Projected Energy Bill Savings in Pilot Projects

For both pilot cases, household energy bill savings have been estimated for the periods **up to 2027** and **beyond 2027**, as shown in **Table 4**. The underlying input parameters, including electricity prices and feed-in tariff assumptions, are provided in **Table 5**. These are based on Dutch averages, as provided in a recent study by Woonbond, Aedes and RVO (Volkshuisvesting Nederland, 2025).

electricity yield/year	Self-consumption	Monthly saving <2027	Monthly saving >2027
960 kWh (Hoptille)	30% (Low)	€17.04	€9.15
1088 kWh (Hoptille)	30% (Low)	€19.31	€10.37
960 kWh (Hoptille)	60% (High)	€19.68	€15.12
1088 kWh (Hoptille)	60% (High)	€22.30	€17.14
624 kWh (Balcony)	40% (Low)	€11.65	€7.24
720 kWh (Balcony)	40% (Low)	€13.44	€8.36
624 kWh (Balcony)	70% (High)	€13.36	€11.12
720 kWh (Balcony)	70% (High)	€15.42	€12.84

Table 4: Estimated energy bill savings per household for Hoptille and Balkoncentrale

In Hoptille, each applied home will be fitted with four 320 Wp solar panels mounted in an east–west configuration. We assume an annual yield of **0.75–0.85 kWh/Wp**, corresponding to **960–1,088 kWh** per system. For the Balkoncentrales, the balconies are fitted with three 320 Wp solar panels, mounted vertically. We assume an annual yield of **0.65–0.75 kWh/Wp**, corresponding to **624–720 kWh** per system.

Although MilieuCentraal (2025) reports an average household self-consumption rate of 30% for eight new panels, we adopt a broader **30–60% range for Hoptille and a 40-70% range for the Balkoncentrales**. This reflects both the smaller installation size (three/four reused panels instead of eight) and the fact that residents will receive advice on timing high-load appliance use to better match their solar production.

We will track actual self-consumption rates to more precisely quantify financial outcomes. In parallel, we aim to build a predictive model that estimates household self-consumption based on annual energy demand and rooftop or balcony solar potential. With this tool we can equip energy-advice services, such as Energiewending, with the insights needed to rapidly evaluate the feasibility and projected impact for future projects.

	Until 2027	2027 onward
Electricity price incl. taxes	0.290 €/kWh	0.290 €/kWh
Feed-in subsidy (saldering)	100%	0%
Feed-in costs incl. taxes	0.110 €/kWh	0.050 €/kWh
Feed-in reimbursement incl. taxes	None	0.090 €/kWh
Service costs	None	None

Table 5: Input parameters electricity prices and feed-in assumptions

Starting in 2027, the Netherlands will end the feed-in subsidy, making self-consumption the main source of economic benefit from solar power. Since the municipality and housing corporation cover all upfront costs, participating households pay no service fees and continue to benefit from on-site solar generation.

#### 4.4 KPI 4: Creation of Jobs for Marginalized Individuals

##### Current social work in reuse chain (PSO-Trede 3) for solar panels

Based on data provided by the reuse chain partners, we estimate that at this stage each solar panel requires 0.57 hours of social work (sorting, cleaning, testing and packaging). So far 2040 solar panels have been packaged for reuse, equalling 1,163 hours of social work. We aim to have packaged 4000 solar panels ready for reuse by the end of this year, equalling 2,280 hours of social work (1.2 FTE).



Figure 5: solar panels tested at Refurn B.V.

##### Larger volume, higher efficiency, more products

We aim to scale up the solar panel reuse chain, which will increase the demand for social labour while also offering opportunities to improve efficiency. As volumes grow, certain processes can be automated, reducing the time required per panel. Currently, the reuse chain focuses solely on solar panels. Although some suppliers already offer refurbished mounting materials, scaling reuse for other balance-of-system components is essential to lower operational costs and build a fully integrated reuse chain. We are actively collaborating with our partner network to enable this expansion and will provide further updates on these developments in the final CNCA report.

##### Creating Opportunities for Local Installers in a Volatile Market

Due to the dynamic political landscape, the demand for solar panels faces sudden disruptions, creating high uncertainty for installers (Solarmagazine, 2024). By initiating new pilot projects, we aim to dampen this effect and continue demonstrating the impact of an inclusive energy transition. These projects provide short-term stability and also contribute to building a resilient workforce that is equipped for the energy systems of the future.



Figure 6: Second-hand solar panels installed at the Marineterrein by local installers from Southeast

#### 4.5 KPI 5: Establishment of Replicable Solar Panel Reuse Chain

At this pilot stage, each project requires considerable overhead and upfront investment. However, our mission is to learn by doing: by analyzing and keeping track of successes and setbacks, we can uncover the levers that enable PV system reuse and directly advance an inclusive energy transition. We maintain full transparency – sharing data, methodologies, and outcomes – so that other municipalities and organizations can readily adopt, adapt, or support our approach. Our work has already attracted national attention, among others, in Solar Magazine (2025) and Het Parool (Koenis, 2025).

To support new partnerships, we have prepared a dedicated Q&A document for housing corporations, which can be found in **Appendix D**, and we will host a Q&A session with interested municipalities. In the final CNCA report, we will present all our insights and recommendations for replicating and scaling this initiative.

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# Appendix A – Loan Agreement for PV-Systems

## THE UNDERSIGNED:

The City of ....., located at ....., legally represented by [name], [position], hereinafter referred to as the "Lender";

and

Housing Corporation ....., located in ..... at [address], legally represented by....., hereinafter referred to as the "Borrower";

Hereinafter jointly referred to as the "Parties" and individually as a "Party".

## WHEREAS:

- The Lender is the owner of solar panels sourced from the reuse chain;
- The Borrower intends to use these solar panels for its residential properties and tenants in .....
- The Parties agree that the Lender will loan the solar panels to the Borrower;
- The solar panels will be delivered by ..... from the reuse chain;
- The Borrower will contract ..... to install the solar panels and related materials at its own expense;
- The Parties wish to record the terms of this loan in the present agreement (hereinafter: "the Agreement").

## AGREE AS FOLLOWS:

### Article 1: Object of the Loan

1.1 The Lender loans to the Borrower, who hereby accepts, [number] solar panels (hereinafter: the "Solar Panels") from the reuse chain.

1.2 The Lender also loans mounting materials, cabling, inverters and optimizers (collectively referred to as the "Mounting Materials").

1.3 If the listed Solar Panels or Mounting Materials are no longer available, equivalent items with comparable specifications and age will be provided.

1.4 The Solar Panels and Mounting Materials (collectively: the "Solar System") remain the property of the Lender throughout the term of this Agreement.

## **Article 2: Duration and Termination**

2.1 This Agreement enters into force on [start date] and remains valid indefinitely until terminated.

2.2 Either Party may terminate this Agreement with six (6) months' written notice.

2.3 Termination must be made in writing.

2.4 This Agreement also terminates automatically when all tenants have vacated the relevant properties in .....

2.5 Upon termination for any reason, ownership of the Solar System transfers to Stichting Zonnex.

## **Article 3: Use**

3.1 The Borrower shall use the Solar System exclusively for the project in ....., where the system will be installed on residential buildings. .... will install the system on behalf of the Borrower.

3.2 The Borrower may not, without prior written consent from the Lender, transfer the Solar System to third parties or install it at locations other than the designated buildings in .....

3.3 The energy benefits of the Solar Systems will go directly to the residents (tenants of housing corporation ..... ) of the respective homes in .....

## **Article 4: Compensation**

4.1 The Borrower agrees to pay ..... a fee of ..... excluding VAT per solar panel as a contribution to the costs of the reuse chain.

4.2 The total compensation of €[total amount] for [number] solar panels will be paid to ..... after the loan agreement between the Borrower and its tenants has been signed. The Borrower is responsible for providing the necessary invoice details to the foundation.

## **Article 5: Installation and Maintenance**

5.1 The Borrower shall contract ....., or another designated supplier, to install, replace, and remove the Solar Systems in accordance with all applicable safety and building regulations.

5.2 The Lender shall reimburse the Borrower for the installation costs of the Solar System on the designated buildings in .....

5.3 The Borrower is responsible for the costs of maintenance, repairs, possible replacement or removal, and insurance of the Solar Systems. Upon removal, ..... will collect the Solar Systems from the ..... site at its own expense upon request of the Borrower.

5.4 The Borrower is obligated to manage and maintain the Solar Systems with due care.

5.5 In the event of damage or defects to the Solar Systems, the Borrower shall notify the Lender immediately and coordinate with ..... and the Lender on the appropriate course of action, whether repair, removal, or replacement.

#### **Article 6: Liability**

6.1 The Borrower is liable to the Lender for any damage to the Solar Systems that occurs during the term of this Agreement, unless the Borrower can demonstrate that they are not at fault.

6.2 The Borrower indemnifies the Lender against third-party claims related to the installation and use of the Solar Systems.

6.3 The Lender is not liable for any damage incurred by the Borrower as a result of defects in the Solar Systems.

6.4 If a delivered solar panel or part of the Mounting Materials proves defective through no fault of the Borrower, the Lender shall provide a replacement free of charge.

#### **Article 7: Miscellaneous**

7.1 Amendments to this Agreement shall only be valid if made in writing.

7.2 This Agreement is governed by ..... law.

7.3 Any disputes arising from this Agreement shall be submitted to the competent court in .....

Agreed and signed in duplicate in ..... on [date].

# Appendix B – Tenant Letter Free Solar Panels

Date: [Insert Date]

Department: [Insert Department]

Phone: [Insert Phone Number]

Email: [Insert Email Address]

**Subject: Unique opportunity: join the free solar panel program for [Neighborhood Name]**

Dear [Tenant Name],

Good news! The roof of your single-family home is suitable for solar panels. Municipality [X] is working together with housing corporation [Y] to offer free solar panels to you and your neighbors.

## **Save on your energy bill!**

With solar panels on your roof, you will generate part of your own electricity. This means you will no longer have to buy this portion from your energy supplier, which is expected to save you around €210 per year. You can find more details about this calculation in the attachment. Want to save even more? Use appliances like your washing machine or dishwasher during the day when the sun is shining. That way, you make direct use of your own solar power.

**[The solar service partner]** will install the panels for you. They will visit your neighborhood and contact you by phone to explain the offer in more detail.

Housing corporation [Y] is currently making future plans for the homes in [Neighborhood]. Municipality [X] is aware of these plans. In the meantime, the free solar panels will help lower your electricity bill. The housing corporation guarantees that your rent will not increase due to the improved energy label your home will receive from the solar panels.

## **How can you sign up?**

Participation is entirely up to you. This is a one-time offer, so you can sign up until [Sign-Up Deadline]. You can sign up in three ways:

1. Send the completed agreement back in the enclosed reply envelope (no postage needed).
2. Visit the website and enter your details. You will then receive an email to sign the documents online.
3. Drop your agreement in the mailbox at [Local Office Address]

**Do you have any questions?**

Would you like more information about the solar panels? Please contact [the solar partner] by calling [Insert Phone Number] or by emailing [Insert Email Address].

We hope you are excited about this great opportunity to lower your electricity bill.

**Best regards,**

Municipality [X], Project Manager Solar Energy, [Name]

Housing Corporation [Y], Property Coordinator, [Name]

[The solar partner], [Contact Person], [Insert Phone Number]

# Appendix C – CO<sub>2</sub>-Analysis

## C.1 Case study specifics for CO<sub>2</sub>-analysis

Specs use-case for CO <sub>2</sub> -analysis	
Size modules	1.7 m <sup>2</sup>
Remaining peak power per module	320 Wp
Installation year	2025 -
De-installation year	2035 -
Number of panels per household	4 panels
Peak power full installation 2025	1280 Wp
Specific yield in the Netherlands	0.96 kWh/kWp/year
Performance ratio	0.84 -
Linear degradation solar panels	0.005 Wp/year

## C.2 Avoided emissions use-case CO<sub>2</sub>-analysis

AVOIDED EMISSIONS DURING USE-PHASE											
Dynamic CO <sub>2</sub> -intensity Dutch electricity grid (projection) [1]	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	
Grid CO <sub>2</sub> -intensity fossil-free in 2035 [2]	0.214	0.193	0.171	0.150	0.129	0.107	0.086	0.064	0.043	0.021	
Grid CO <sub>2</sub> -intensity fossil-free in 2040 [3]	0.236	0.221	0.207	0.192	0.178	0.163	0.149	0.134	0.120	0.105	
Grid CO <sub>2</sub> -intensity fossil-free in 2045 [4]	0.257	0.246	0.236	0.225	0.214	0.204	0.193	0.182	0.171	0.161	
<b>CO<sub>2</sub>-savings due to solar electricity use</b>	<b>2025</b>	<b>2026</b>	<b>2027</b>	<b>2028</b>	<b>2029</b>	<b>2030</b>	<b>2031</b>	<b>2032</b>	<b>2033</b>	<b>2034</b>	<b>TOTAL AVOIDED EMISSIONS [kg CO<sub>2</sub>-Eq]</b>
Yearly electricity yield full installation (4 panels)	1032.2	1027.0	1021.9	1016.7	1011.5	1006.4	1001.2	996.1	990.9	985.7	9103.9
CO <sub>2</sub> -saving FF 2035 [2]	221.2	198.1	175.2	152.5	130.1	107.8	85.8	64.0	42.5	21.1	977.1
CO <sub>2</sub> -saving FF 2040 [3]	243.3	227.2	211.2	195.4	179.7	164.2	148.8	133.6	118.5	103.6	1725.5
CO <sub>2</sub> -saving FF 2045 [4]	265.4	253.1	240.9	228.8	216.8	204.9	193.1	181.4	169.9	158.4	2112.6
<b>Shadow cost savings due to solar electricity use</b>	<b>2025</b>	<b>2026</b>	<b>2027</b>	<b>2028</b>	<b>2029</b>	<b>2030</b>	<b>2031</b>	<b>2032</b>	<b>2033</b>	<b>2034</b>	<b>TOTAL AVOIDED SHADOW COSTS [EUROS]</b>
CO <sub>2</sub> -pricing City of Amsterdam [5]	0.448	0.463	0.480	0.496	0.514	0.432	0.550	0.570	0.589	0.610	-
Shadow cost saving FF 2035 [2]	99.1	91.7	84.1	75.6	66.8	46.6	47.2	36.5	25.0	12.9	585.6
Shadow cost saving FF 2040 [3]	109.0	105.2	101.4	96.9	92.4	70.9	81.8	76.1	69.8	63.2	866.8
Shadow cost saving FF 2045 [4]	118.9	117.2	115.6	113.5	111.4	88.5	106.2	103.4	100.1	96.6	1071.4

### Assumptions for CO<sub>2</sub> calculation of avoided emissions

1. The Dutch electricity mix will be completely fossil-free between 2040 and 2045 and will decarbonize linearly starting from the [grid intensity](#) as determined by CBS in 2021
2. Scenario from the [National Energy System Plan](#), Government of the Netherlands (2023)
3. Plausible scenario: fossil-free electricity grid by 2040
4. Pessimistic scenario: fossil-free electricity grid by 2045
5. Application rule for sustainable investments (2023): internal, City of Amsterdam

### C.3 Induced emission use-case CO2-analysis

EMISSIONS			Reused panels [1]	New inverters [2]	Reused mounting system [3]	TOTAL	SHADOW COSTS [€]
Phase	Phasing (EPD)	Activity	[kg CO2-Eq]	[kg CO2-Eq]	[kg CO2-Eq]	[kg CO2-Eq]	[€]
Production	A1-A3	Extraction of raw materials, transport to manufacturer, production process	NONE [4]	64.62	NONE [4]	64.62	28.95
Installation	A4	Transport to usage location	2.04	2.12	0.72	4.88	2.18
Installation	A5	Installation at usage location	8.33	0.07	4.04	12.44	5.57
Use-phase	B1-B7	Use of product (see avoided emissions for CO2-savings due to use)	0.00	72.57	0	72.57	32.51
End-of-Life	C1	Demolition	0.00	0.00	0	0.00	0.00
End-of-Life	C2	Transport to waste processing	0.41	0.29	0.28	0.98	0.44
End-of-Life	C3	Waste processing processes	N.a. [5]	0.02	N.a. [5]	0.02	0.01
End-of-Life	C4	Landfilling	N.a. [5]	0.52	N.a. [5]	0.52	0.23
End-of-Life	D	Recovery of raw materials	N.a. [5]	-5.09	N.a. [5]	-5.09	-2.28
Sum	A1-D	ALL ACTIVITIES	10.78	135.13	1.26	147.16	65.93

#### Assumptions CO2-calculations emissions PV-system

1. Calculations based on the [most recently available EPD](#) of a c-Si solar panel used at residential level:
2. Calculations based on [EPD Solaredge inverter](#) (9.3kW) scaled to an inverter with a DC capacity of 1150W
3. Calculations based on [EPD Sunbeam Nova](#) (flat roof mounting system)
4. No production phase for directly reused materials
5. Recycling is only postponed. Avoided emissions are already included in EPDs of new materials. Avoid double counting
6. 0.448 €/kg CO<sub>2</sub> (CO<sub>2</sub> pricing, City of Amsterdam, 2023)

## Appendix D – Q&A Housing Corporations

Below you'll find answers from the City of Amsterdam to additional questions raised by housing corporations after the presentation of the Solar Program Team at the AFWC Sustainability Network on June 12, 2025.

**Q: Under the proposal, the solar panels remain owned by the city, and we sign a user agreement with the city. The corporation selects a building, conducts an inspection, notifies tenants, and installs the PV panels. The invoice goes to the city, and the corporation handles any subsequent maintenance. Is this correct?**

**A:** That is broadly correct. The installation is carried out by the corporation's installer, who is also responsible for service, management, and maintenance after installation, as is customary. At this stage, other cooperation models are also possible, as described below.

**Q: Is the following approach also possible for the city?**

*The corporation selects a building and facilitates the process. The city notifies the tenants and asks who wants to participate (in the case of individual connections). The city arranges for installation of the PV system. We jointly arrange a right of superficies (since the roof is owned by the corporation). The city manages the PV system.*

**A:** Yes, this is certainly possible. We would then explore together how best to organize this, so it's clear who is responsible for what activities and materials. In an earlier pilot, we deliberately chose to align with existing practices so that the corporation knows exactly whom to contact for service. It's important that we make clear agreements on how to organize service and monitoring as clearly as possible.

Note that the city does not have the capacity within this project to guide decision-making processes within homeowners' associations (VvEs). Our aim is to achieve as many individual connections as possible so that tenants directly benefit.

Within the city's installation network, we can recommend installers with experience in reuse projects who can ensure quality and warranty.

If desired, one of our reuse network partners can offer a one-day course for local installers on installing second-hand PV systems. This ensures that reused materials are installed reliably and efficiently.

**Q: Will all costs be covered by the city?**

**A:** First, in general: we are currently in a pilot phase where we want to test and learn. This means (for projects and agreements made in 2025) that more may be possible than from 2026 onward. The city intends to cover costs for:

- Inspection of the relevant home(s)
- The solar system (panels, inverter, mounting material, cables, etc.)
- Installation of the systems (including a standard route and connection to the fuse box)
- A P1 monitor (optional) to view self-consumption
- Service in the first year after installation

What we believe should logically be paid by the corporations:

- Upgrading/modernizing the fuse box
- Creating roof penetrations
- Service/maintenance after the first year
- Contribution per panel to the reuse chain, to replenish the stock for other projects

However, as noted, this is a pilot phase, so please tell us if you see it differently or need something else.

**Q: Specifically, what about costs for permits and roof structure checks?**

**A:** This is negotiable and depends on the situation.

**Q: Are the costs for cabling to the home and possibly adapting or expanding the fuse box also covered by the project budget?**

**A:** Cabling to the fuse box is part of the solar system installation.

If the fuse box is outdated or unsuitable for connecting solar panels, then adaptation or replacement is considered the responsibility of the housing corporation.

**Q: What about maintenance costs, since old panels could break down sooner?**

**A:** The panels are all inspected and tested, making the chance of early failure minimal. If any parts turn out to be faulty after professional installation, replacement parts will be supplied through the reuse chain.

We require installers to offer at least a one-year warranty on the installation, in addition to any manufacturer warranty.

We aim for maintenance costs to be covered under the contracts corporations already have with their installers. That's why, in the first pilot, we chose to use the corporation's usual

installer. This builds on existing trust and ensures that if something goes wrong, the corporation and installer can rely on their existing maintenance/service agreements.

**Q: Can we use our own installers for, for example, ongoing maintenance?**

**A:** Absolutely. This also makes it clearer.

As mentioned earlier, we can also have installations carried out by other parties experienced in reuse projects. The key requirement is that they offer at least a one-year installation warranty.

**Q: We would also like our usual roof partners to handle roof penetrations. Will the city reimburse these costs?**

**A:** Using your usual roof renovation partners sounds sensible. We expect these costs to be borne by the corporation.

**Q: Will conduit pipes be installed to the homes, and can these be reused later (for example after temporary roof replacement)?**

**A:** Whether conduit pipes are used depends on the situation. We will assess on a case-by-case basis what makes sense.

Note that the panels we have in stock are only five years old and can likely last another 20 years. For roofs available only for a few years, slightly older panels might be more appropriate, and vice versa.

**Q: Will maintenance and repair invoices go through the city?**

**A:** The principle is that the city pays for the installation and a warranty period (1 year). Further maintenance and service should ideally be covered by the corporation's existing maintenance contracts.

**Q: Will the city also pay for a SCOPE 12 inspection?**

**A:** Yes, we consider this part of the installation.

**Q: If it's free for tenants and they don't pay a service fee, do we still need to monitor?**

**A:** We want to monitor system performance and tenants' self-consumption, at least initially. This helps demonstrate the performance of reused systems and provides insight into future financial benefits for tenants, especially once net metering is phased out.

We could also add energy coaching to help tenants maximize the benefits of their solar system. Sharing tenants' energy data is always optional and not a condition for participating in this project.

**Q: What is a practical way to select buildings/homes?**

**A:** We focus on residential complexes with:

- Poor energy performance (energy label E, F, or G);
- No confirmed renovation plans by the owner within 5 years, or temporary housing (like flex homes);
- A high degree of energy poverty ( $\geq 10\%$  of household income spent on energy).

At this stage, these criteria serve as guiding principles rather than strict requirements so we can learn and adjust based on pilot experiences.

We work with energy-saving services like De Energiewending, De Groene Hub, Stichting WOON! and other local initiatives that have direct contact with residents. They can conduct an initial assessment, after which we can schedule inspections or feasibility studies for promising complexes.

In Amsterdam Southeast, for example, a housing corporation's property manager suggested a complex that met these criteria. We are keen to engage with more property managers to identify such opportunities.

**Q: What budget is available and for how many homes?**

**A:** Our goal is to have installed solar panels at 1,000 households by the end of 2026, largely funded by the Climate Fund. Actual realization will depend on investment costs. Therefore, we assess feasibility for each project in relation to societal value, such as reducing energy poverty, CO<sub>2</sub> reduction, and use of social labor.

**Q: Is this easily scalable?**

**A:** Yes. Once we've set up some practical arrangements, it's very scalable. There are enough materials circulating to equip many homes with quality reused systems.

If we standardize agreements (like loan agreements, cost allocation, and installer arrangements), we can build scale quickly. The first steps in standardization have already been taken in the pilots.

Together with our reuse chain network, we're exploring how to significantly lower material costs by optimizing cooperation. There's still a lot of untapped potential. By also integrating the assembly of complete PV systems – including refurbished mounting materials and inverters – the business case becomes much more attractive. This development started within

the CIRCO chain track and will be further professionalized next year under a national chain coordinator.

**Q: In other words, if it's only a small number of homes, might the corporation's workload outweigh the benefits?**

**A:** We are focused on scalability and are keen to work with you to make this practical and manageable. By quickly realizing several pilot projects, we gain valuable experience that forms the basis for a thoughtful, efficient scaling plan, contributing to an inclusive energy transition and renovation effort. We also see this as a meaningful addition to our joint agreements to make solar energy accessible to tenants. Additionally, reuse helps prevent waste and creates valuable jobs within the chain.

Finally, solar energy can make a meaningful difference for vulnerable tenants. We'd be happy to start working with corporations who, like us, are willing to invest energy to make this a success.

**Q: What about balcony systems?**

**A:** A pilot is currently underway in Amsterdam West (with Ymere). We see growing interest in these systems, which may also be installed as tenant-installed improvement/fixture.

As part of this pilot, we're assessing how to install these systems safely, how much they deliver in different scenarios, and whether permits are required. Certified installers and the fire department are involved. Based on the results, we'll decide whether balcony systems are worthwhile and if scaling up is feasible and desirable