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Sustainability Plan for Energy Community in Terraced Housing Company

Part D 3.5 of the
StartSun – Start-ups for Solar Energy Communities

This publication is part of the implementation of Work Package 3 (WP3) of the StartSun (*Start-ups for Solar Energy Communities*) project. It serves as a follow-up to the project's main output *Start-up Package: From Establishing to Managing a Solar Energy Community*, which also served as the basis for this document. Information may differ between the original report and this one, as data and calculations have been updated for this publication. The assessment of the economic viability and environmental impacts outlined in this sustainability plan covers a 25-year system lifecycle.

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Introduction

This report focuses on the sustainability plan for a solar PV community and system, examining a six-unit terraced house complex in Marttila, Southwest Finland. The terraced house pilot was identified through the "Energy Transition in Housing Companies" (Finnish ERDF project, acronym "TEMU") project. The goal of TEMU is to promote the transition of housing companies toward sustainable energy solutions. The project's partners are Turku University of Applied Sciences and Valonia (an expert organization for sustainable development serving municipalities in Southwest Finland).

Sustainability is examined from four closely interconnected perspectives (Figure 1): economic, technical, environmental, and social.

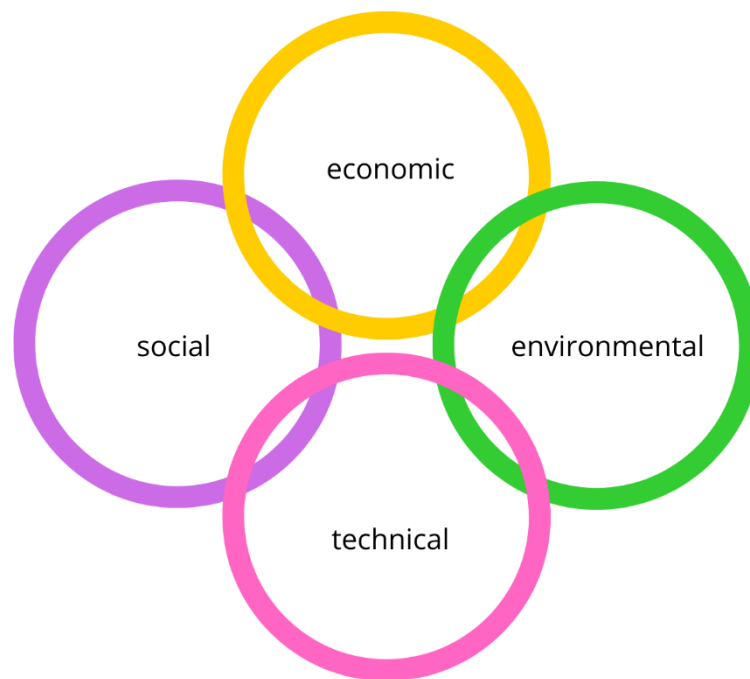


Figure 1. Aspects of the sustainability of a photovoltaic system.

The report is structured to include separate chapters for each aspect of sustainability, applying the assessments and results to the terraced house:

- **Economic sustainability** evaluates the economic viability of the solar PV system over its lifecycle.
- **Technical sustainability** evaluates the functionality and safety of the solar PV system, as well as changes occurring over its lifecycle.

- **Social sustainability** evaluates the impact of self-generated solar power on the community (the housing company and its residents/shareholders) and on energy democracy.
- **Environmental sustainability** evaluates the transition from oil heating to a combined solar PV and heat pump solution, as well as the impact of this change on the housing company's CO₂-emissions; end-of-life decommissioning is also considered.
- **Conclusions and reflections** evaluate the integration of economic, technical, and environmental sustainability within the context of energy system transitions.

The calculations and data rely on publicly available sources and solar PV calculators ([StartSun](#), [PVGIS](#) ja [FinSolar](#)), while background information regarding the housing company was obtained from the property manager in Marttila.

Economic sustainability

Examining economic sustainability ensures that the investment is reasonable, profitable and productive in the long term. This review evaluates the impact of electricity price fluctuations, cumulative savings achieved over the lifecycle, and the payback period of the system. In addition, the conditions in which the system produces the greatest financial benefit were identified, such as a high degree of self-use or a significant increase in the price of electricity. The economic review supports decision-making and helps to evaluate the added value produced by the investment for the property owner.

The baseline data for the profitability calculations

The baseline data for this document is based on the Marttila terraced house project presented in the [Start-up Package](#) (Table 1), which was used to perform detailed profitability calculations. The solar PV system has been sized based on the site's annual consumption profile.

Table 1. Basic description of a solar PV system

System power (kWp)	12
Investment price (€)	12 000
Production in a year, 1st year (kWh)	11 500
System's lifespan (years)	25
Panel efficiency degradation (% / year)	0,5
Maintenance and repair costs (O&M) (€/year)	120
Inverter replacement after 15 years (€)	2 500
Discount rate % (discounting rate / opportunity cost)	3
Average electricity consumption of the housing company before AWHP investment (kWh/year)	3 215
Initial electricity purchase price according to capacity-based distribution contract (€/kWh)	0,134
50% of production for own use (kWh/year)	5 750
Sales electricity price (€/kWh)	0,04

Based on this initial data, the annual solar power generation forecast was determined using the [PVGIS calculator](#). The inputs entered the calculator included the address of the Marttila pilot site, the solar power system's size (12 kWp), and the PVGIS-recommended optimal panel orientation (-4° South) and tilt angle (45°). The generation forecast focused on the period from March to September, as there is no significant generation during the winter months. The projected annual yield is approximately 11,500 kWh, with 9,850 kWh generated

between March and September. PVGIS estimates the system loss at 14%. Figure 2 illustrates the distribution of generation throughout the year in greater detail.

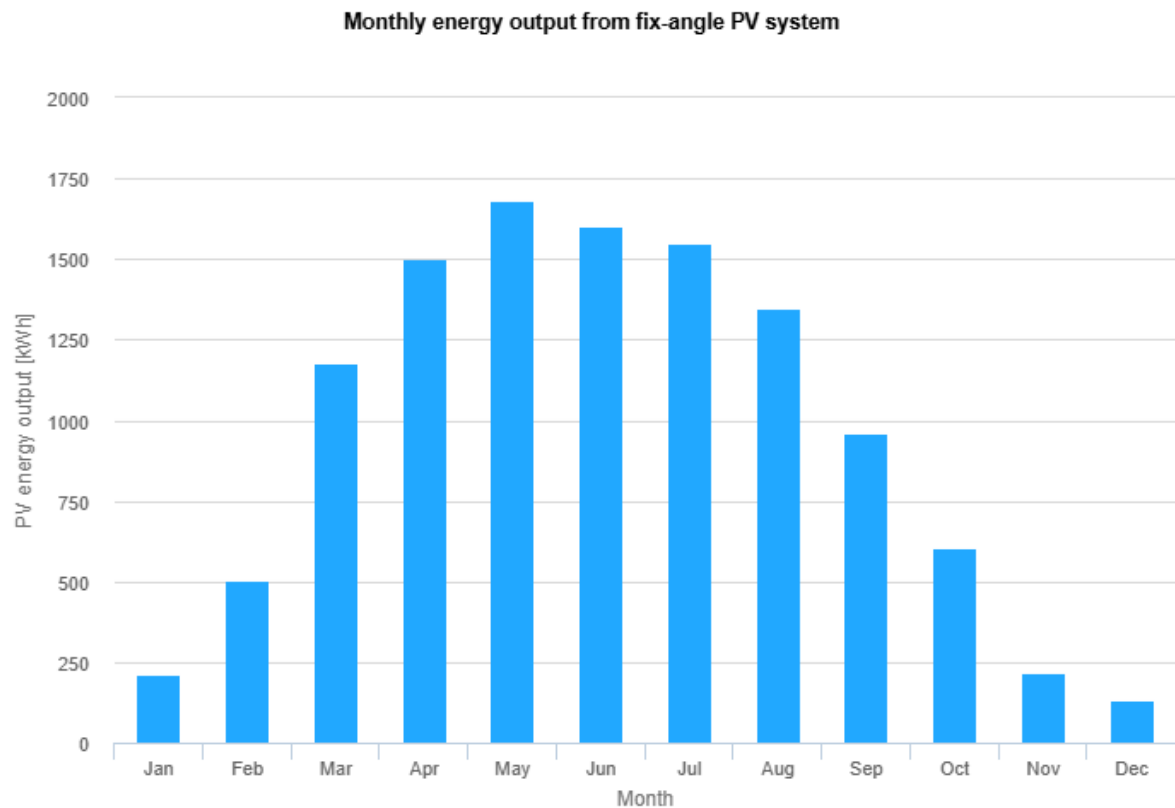


Figure 2. Monthly production breakdown

Assessment of electricity price increases

The calculations considered three different price scenarios for the annual increase in electricity costs:

1. prices remain unchanged
2. the price rises by 3% annually, representing a moderate yearly increase
3. the price rises by 8% annually, corresponding to the maximum annual price increase permitted by the Energy Authority

Each scenario accounted for the components of the total electricity price:

- electricity spot price
- electricity distribution under a general distribution contract (0.0526 €/kWh in the Caruna Oy area)
- electricity tax (0.0292 €/kWh, rate since 1 April 2026)
- fixed monthly fee for a 63 A fuse (138.75 €/month)

Monthly average spot prices were retrieved from [Pörssisähkö.net](https://pörssisähkö.net) price statistics for the years 2023–2025, and a monthly average was calculated based on these years (Figure 3). Additionally, the calculations considered two different self-consumption rates for the generated electricity: consuming the entire production or consuming half of it. The analysis period for the scenarios is 25 years, corresponding to the expected lifespan of the solar panels.

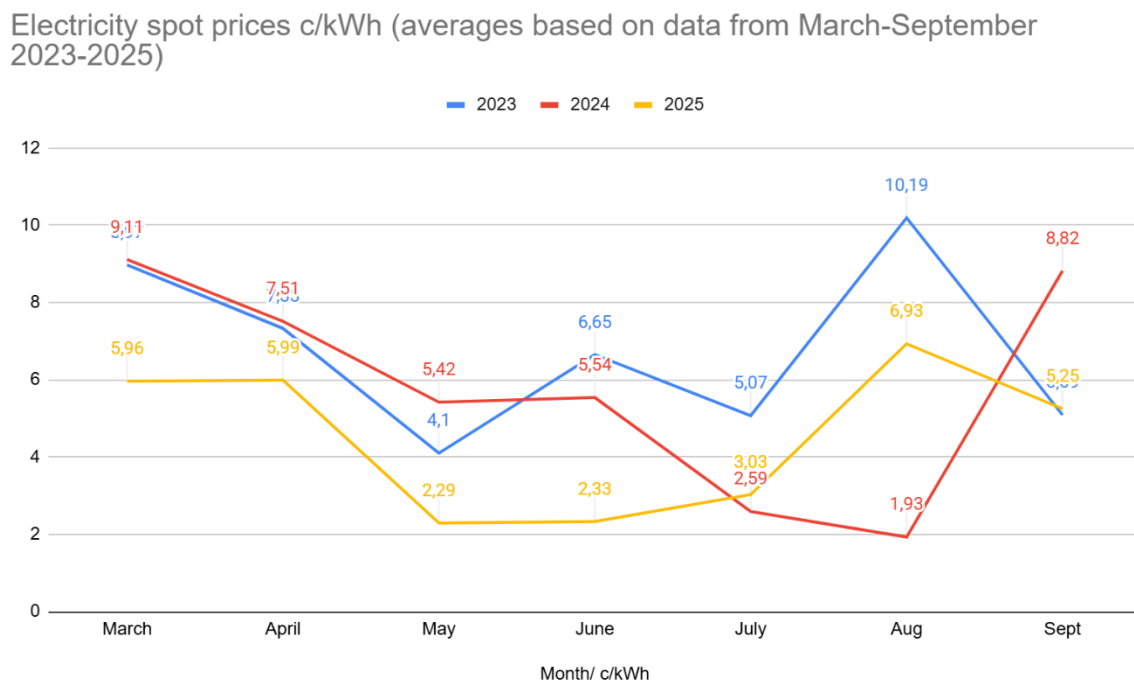


Figure 3. Electricity spot prices 2023–2025

Results of profitability calculations from various perspectives

For a housing company, acquiring a solar power system is a long-term investment which true economic value is difficult to grasp using a single metric. A solitary figure—such as the payback period alone—can easily provide an overly narrow or even misleading picture of the project's profitability.

This study examines the investment from three main perspectives to provide the most comprehensive and realistic overview possible as a basis for decision-making:

1. **Levelized Cost of Electricity (LCOE):** Indicates the cost to the property of self-generating one kilowatt-hour of electricity over a 25-year period, accounting for all lifecycle costs and equipment replacements. This

enables a direct comparison between solar electricity and the cost of purchased electricity.

2. **Cumulative electricity bill savings:** Illustrates the benefits provided by the solar power system, considering potential electricity price increases under various scenarios and the rate of self-consumption.
3. **Discounted Payback Period (DPBP):** Reflects the investment's risk level and the speed at which the committed capital is recovered through the housing company's cash flow.

In addition, the calculations account for the property's specific parameters (such as the DSO's distribution contract types) and include a sensitivity analysis regarding the self-consumption rate and fluctuations in electricity prices.

Levelized Cost of Electricity (LCOE) and Discounted Payback Period (DPBP)

The LCOE represents the actual unit cost (€/kWh) of solar electricity generation over the entire 25-year lifecycle, with all costs and output discounted to present value (using a 3 % discount rate). Table 2 shows the calculated levelized cost of electricity for the property: **8.3 cents/kWh**. This is significantly lower than the cost of electricity purchased from the grid (approximately 13.5–14.4 cents/kWh), making the generation highly competitive throughout the lifecycle.

Table 2. LCOE calculations

LCOE, €/kWh	0,083
Present value of life cycle costs, €	15 694
Present value of an annuity (regular annual payment) PNA, €	2 090
Inverter replacement in year 15 (€2,500, 3% discounted)	1 605
Discounted production over the life cycle, kWh	190 127

The DPBP indicates the payback period during which the investment's cash flows—discounted to their present value—cover the initial investment. Table 3 presents the calculations for the investment's nominal cash flow, discounted cash flow, and cumulative present value. The payback calculation accounts for an annual 8 % increase in electricity purchase and sales prices. The cumulative present value **turns positive between years 11 and 12**, marking the point at which the investment has been paid back, accounting for interest and degradation.

Table 3. DPBP calculations

Year	1	5	10	11	12
Nominal cash flow (€/year)	806	1 112	1 641	1 772	1 912
Discounted cash flow at 3% interest and 0.5% degradation (€/year)	782	959	1 221	1 280	1 341
Cumulative present value (€)	-11 218	-7 654	- 2 091	-811	530

Savings on the total price of electricity (with 50 % self-consumption)

Ultimately, six analysis scenarios were established: two different self-consumption rates (50 % and 100 %) and three different electricity price trajectories (0 %, 3 %, and 8 % annual increases). Total savings over a 25-year lifecycle, if 50 % of the generated solar electricity is consumed within the housing company:

- with no price changes: approximately 29,000 €
- with a 3 % annual price increase: approximately 42,500 €
- with an 8 % annual price increase: approximately 85,000 €.

Payback time

The initial investment for a 12 kWp solar PV system is approximately 12,000 €. The total cost comprises installation (50 %), solar panels (25 %), the inverter, and mounting systems and cabling (10 %). In addition to the initial investment, system maintenance incurs annual costs amounting to a few percent of the initial investment.

The payback calculation accounts for annual electricity savings and fixed annual costs of 120 €. With 50 % self-consumption of the solar electricity generated, the payback period is:

- 11–12 years without price changes
- 9–10 years with a 3 % annual price increase
- 8–9 years with an 8 % annual price increase.

Comparison of distribution agreements (General distribution vs. Capacity-based distribution)

At the time of writing (August 2026), the calculations are based on the general electricity distribution contract (63 A) price list of Caruna Oy. The terraced house complex serving as the pilot site for the StartSun project has a capacity-based

distribution contract. Both the fixed charges (€/month) and the distribution rates (cents/kWh) differ between these two contracts (Table 4).

Table 4. Comparison of transfer agreements

Cost (€/month)	General distribution for 63 A	Capacity-based distribution 1 PJ
Basic fee	138,75	73,67
Capacity-based distribution (2x16 kWh AWHP)	-	143,36
Reactive power charge	-	3,46
Distribution fee	100	84
Total (€/month)	239	304
Total (€/year)	2 864	3 654

Under the capacity-based distribution contract (160 A connection size), the variable distribution energy price is 4.42 cents/kWh, whereas under the general distribution contract, it is 5.26 cents/kWh. Since the savings generated by self-consumed solar electricity are derived from the variable components of the purchased electricity being replaced (electricity energy + distribution energy + electricity tax), each self-consumed kilowatt-hour yields slightly lower savings under the capacity-based distribution contract than under the general distribution contract (13.56 cents/kWh vs. 14.40 cents/kWh); see Table 5. Based solely on electricity consumption (distribution + tax + energy), the capacity-based distribution contract yields **annual savings of 168 €** on costs if consumption is 20,000 kWh/year. However, the capacity-based distribution contract's capacity charge (143 €/month) completely offsets 0.84 cents/kWh saving gained on the energy price. At an annual consumption of 20,000 kWh, the 168 € saving achieved on electricity costs is less than the additional cost incurred by the capacity charge. On an annual basis, the capacity-based distribution contract is 789 € more expensive at this level of consumption.

Table 5. Comparison of electricity distribution

Total electricity price [€/kWh]	General distribution	Capacity-based distribution
Distribution	0,0526	0,0442
Tax (since 1.4.2026)	0,0292	0,0292
Purchased electricity	0,0622	0,0622
Total	0,1440	0,1356

Observations and constraints regarding the calculations

The calculations performed are indicative estimates, and the following points should be considered in further analysis:

- **Self-consumption rate:** The 50 % self-consumption rate used in the calculations is optimistic compared to simulation tools (the StartSun calculator estimates a rate of 41 %, and FinSolar 40 %).
- **Inverter replacement:** The inverter replacement cost (2,500 €) in year 15 has been factored into the LCOE calculation (increasing the LCOE by approximately +0.3 cents/kWh). However, the inverter replacement scheduled for year 15 does not affect the discounted payback period (DPBP) result (11–12 years), as the investment pays for itself prior to that time.
- **Panel degradation:** The annual ~0.5% decline in panel efficiency was not factored into the basic payback period calculation (though degradation is accounted for in the LCOE sections).
- **Analysis timeframe:** The comparison was conducted on an annual basis rather than using monthly or hourly consumption profiles.

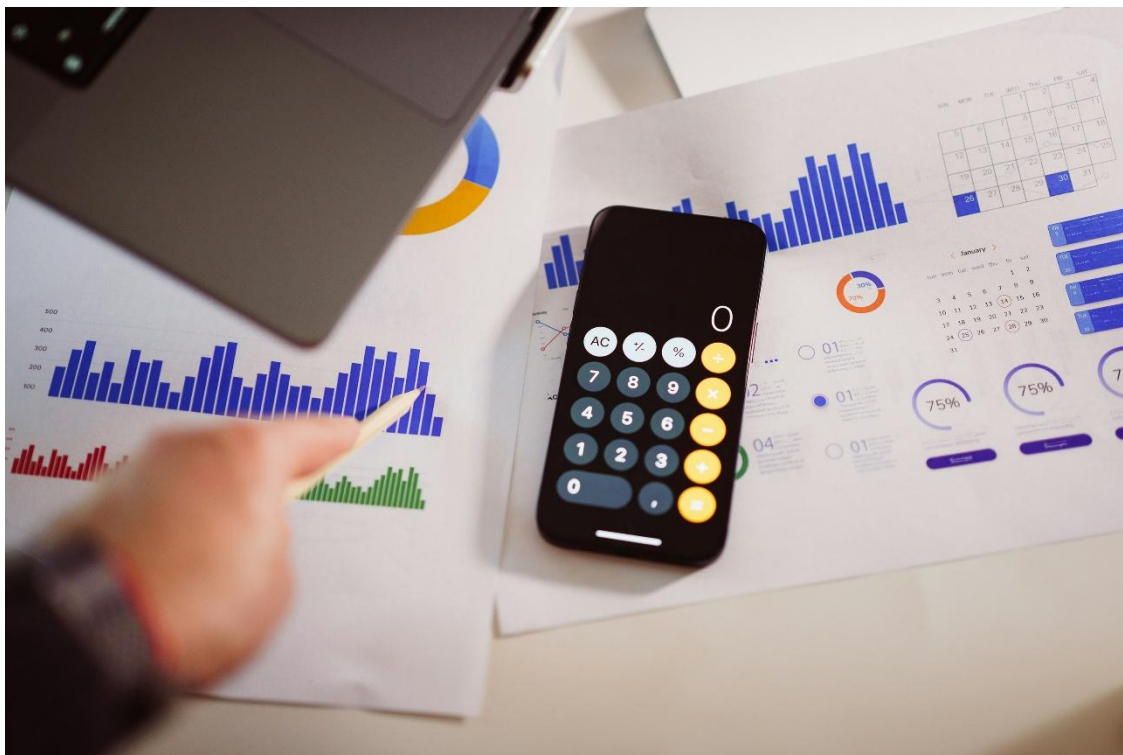


Figure 4. Calculations. Source: Jakub Żerdzicki / Unsplash

Technical Sustainability

A technical sustainability plan for a photovoltaic system ensures that the system operates optimally and safely throughout its expected 25-year lifespan.

Key background information regarding technical sustainability includes:

- Total capacity of the photovoltaic system (kWp)
 - Panel power output (W) and inverter power output (kW)
- Component makes and models (panels, inverters, mounting systems)

Photovoltaic system inverters typically last 10–15 years. The sustainability plan must account—from both economic and technical perspectives—for the fact that inverters will need to be replaced at least once during the system's lifespan. It is also advisable to consider the decline in panel efficiency when assessing economic and technical sustainability, and to estimate its impact on electricity generation after, for example, 7–10 years. Thus, technical and economic perspectives are closely linked when evaluating sustainability.

Selecting the system

When selecting a solar PV system, it is important to examine the following three aspects to ensure the right balance between the system, energy production, and the system's lifecycle:

1. Aligning electricity consumption with system sizing

Compare the building's electricity consumption and load profile with the proposed size of the solar PV system and optimize production to match the building's own consumption as closely as possible.

2. Component sizing and cost-efficiency

Systems should be selected to meet actual operational needs; oversizing (e.g., regarding the inverter) should be avoided, as it increases investment costs without offering benefits. Additionally, future expansion possibilities should be assessed—for instance, regarding compatibility with additional panels, battery storage systems, and inverters.

3. Production trends over the lifecycle

In addition to future expansion potential, factors such as possible participation in reserve markets and the automation of revenue sharing should be considered.

To evaluate optimality, *A scoring matrix for the request for tenders* (Table 6) can be used; this allows for the assessment of features—such as those related to the inverter—prior to procurement. The scoring matrix and its accompanying checklist were developed based on the Marttila terraced house.

Table 6. *A scoring matrix for the request for tenders*

Evaluation criterion	Weight %	Checklist
1. TOTAL PRICE		
Total price (incl. VAT and installation)	25 %	☐ Includes cranes, permits, and notification to Caruna regarding the commissioning of the solar power plant. ☐ Consideration of Caruna's grid distribution charges.
Lifecycle cost (€/kWh, 25 years)	15 %	☐ Based on 25 years of production
2. TECHNICAL QUALITY AND SMART FEATURES		
Inverter and 15-minute metering readiness	10 %	☐ Supports 15-minute settlement intervals ☐ Implementation without separate additional devices
Battery net capacity (kWh)	10 %	☐ Net capacity stated ☐ Warranty stated as retained capacity (%)
Air-to-water heat pump (AWHP) integration	10 %	
3. DOCUMENTATION AND SAFETY		
Warranties	10 %	☐ 25-year performance and product warranty for panels ☐ 10-year warranty for inverter
Commissioning and safety documentation	5 %	☐ FS-EN 62446 report included
4. REFERENCES AND SUPPORT		
Energy community expertise	10 %	☐ References from housing companies and energy communities
Availability of maintenance	5 %	☐ Support service in Finland ☐ Service provider stability
TOTAL	100 %	

System installation

Safety, legislation, and appropriate permits are of paramount importance in the installation of electrical systems. This section outlines the key requirements and checklists for installation work.

A commissioning inspection must be performed upon installation of the system, and a commissioning report must be produced. In addition, appropriate property markings and warning signs must be present at the site. [1]

Three main points regarding installations:

- 1. Ensure proper authorization** (Finnish Safety and Chemicals Agency register): Electrical work may only be performed by a professional listed in the Finnish Safety and Chemicals Agency public register of electrical contractors (rekisterit.tukes.fi/toiminnanharjoittajat). The client or property manager must verify—using the company name or Business ID—that the company holds a valid license (e.g., Class A) and has a designated supervisor for electrical work.
- 2. Documentation and signage:** Upon completion of the installation, the contractor must provide a written commissioning report (certifying a safe installation) and affix the statutory warning labels to the equipment.
- 3. High risk associated with unauthorized work:** If the installer is not listed in the Finnish Safety and Chemicals Agency register, the installation is illegal. In such cases, official documents are invalid, and should the equipment cause a fire or other incident, the insurance company does not cover the damages.

Rule of thumb: Always verify the company via Finnish Safety and Chemicals Agency **before entering an agreement** and request the commissioning report **immediately upon completion of the work**. Without these, you may fail to meet your insurance company's requirements in the event of a loss.

Fire safety of a solar photovoltaic system

It is advisable to consider the safety of a photovoltaic system from the perspectives of both electrical safety and fire safety. Key factors regarding fire safety include high-quality design and installation, safe electrical connections, proper cabling, correct equipment placement, and regular system maintenance. Fires caused by photovoltaic systems are rare and unlikely; when they do occur, they typically stem from design or installation errors.

When planning for the fire safety of a photovoltaic system, the following should be considered:

- Potential space requirements for the inverter and associated costs (e.g., is a separate storage space needed?).
- Adequate ventilation and cooling for the inverter.
- Defining maintenance procedures for the various components of the photovoltaic system (responsibilities, inspection intervals, cleaning).
- Prevention of moisture issues and corrosion. [1]



Figure 5. Inverter. Source: Elite Power Group / Pexels

Routine maintenance procedures

Electrical systems require regular inspection and maintenance to enhance safety. It is advisable to carry out maintenance tasks throughout the year. Regular inspections should include cleaning the inverter's cooling fins and fans, as dust accumulation raises the device's temperature and shortens its service life. In the spring, once the snow and ice have melted, it is worth checking that

the snow has not warped the mounting hardware or panel frames. Ensure that the cables remain clear of the roof surface. A thermal imaging inspection of the panels should be performed on a sunny day every three years. Defective cells appear as overheated spots in thermal images; these can pose a fire hazard or lead to a significant drop in power output.

A separate responsibility matrix (Table 7) has been created for the system, defining who performs the work, who supervises it, and who responds to any deviations. In addition to routine maintenance, it is wise to prepare for lifecycle-related changes—such as roof repairs (e.g., after 7–10 years)—that require the panels to be dismantled and reinstalled.

Table 7. Responsibility matrix

Area of responsibility	Responsible party	Content and terms	Duration / Basis of liability
Operation and maintenance	Housing company (board & property manager)	Regular maintenance, periodic inspections, and adherence to the manufacturer's operating instructions.	Continuous (from the time of handover)
Liability for risk	Housing company (or property insurance)	External damage (e.g., storms, lightning strikes, vandalism).	Continuous (from the time of handover)
Obvious defects	Housing company	Defects clearly observable at the time of handover that were not recorded in the inspection report or reported within a reasonable timeframe.	From the time of handover
Liability during the warranty period	Contractor	Operational malfunctions and component failures, unless caused by the housing company's negligence or an external factor.	According to the contract (usually 2–5 years)
Latent defects / negligence	Contractor	Defects that could not be detected at handover, as well as unprofessional installations (e.g., loose connections, incorrect cross-connections).	Up to 10 years from handover (YSE 1998, Section 30)
Statutory electrical safety	Contractor (Supervisor of electrical work)	Compliance of the installation with regulations and standards (SFS 6000, Electrical Safety Act). Safety defects must always be rectified at the contractor's expense.	Statutory (signing the minutes does not eliminate this)

Social sustainability

An energy system modernization in a municipality-owned rental housing company serves simultaneously as a significant climate action, a financial investment, and a tool for promoting social sustainability. Transitioning from fossil-fuel-based heating to heat pump technology and on-site solar power generation significantly cuts the property's carbon emissions and operating costs. At the same time, it creates a unique opportunity to foster housing equity and combat energy poverty within the municipality's housing stock.

The project's success hinges on aligning two objectives that, while distinct, complement each other:

- **The municipality's interests regarding ownership steering and economics:** Direct use of generated electricity is maximized for equipment connected behind the property's electricity meter (particularly the heat pump). This minimizes property maintenance costs, improves the investment's payback period, and curbs pressure to raise rents.
- **Social sustainability and the horizontal principles of the ERDF project:** Ensuring resident equality, accessibility, and participation. Although the system is sized to meet the property's primary loads, a portion of the solar electricity production can also be allocated to residents—provided that the site's grid connection and ownership arrangements allow for the net billing mechanisms associated with energy communities.

The following recommendations outline concrete steps for implementing the project in a way that is technically and financially smart, administratively seamless, and respectful and inclusive of residents:

- **Human-centric and accessible communication:** Communicate about everyday savings and the mitigation of rent-hike pressures using plain language, multiple languages, and illustrations. Build trust primarily through face-to-face resident meetings and workshops.
- **Two-phase hybrid model and resident engagement:** Direct solar electricity primarily to the heat pump to maximize the municipality's financial objectives. If net metering or credit-based billing is feasible, automatically credit surplus electricity to residents' bills; this alleviates energy poverty without requiring personal investment from the residents.

- **Seamless administration and climate strategy:** Automated credit calculations save property management resources. The project advances the municipality's strategy by cutting property emissions by up to 96 % and reinforcing a socially responsible housing policy.
- **Clear roadmap:** Focus the first year on building trust, implementation, and demonstrating savings. Within five years, refine the experience into a readily replicable operating model for the municipality's other rental properties and, potentially, for terraced house complexes as well.

Environmental Sustainability

Most greenhouse gas emissions from residential properties stem from space heating. The environmental component of the sustainability plan focuses on the impact of the heating system on energy consumption and the reduction of CO₂ emissions. Additionally, the study sought to determine the economic benefits associated with these emission reductions.

The following calculations examine the transition of a terraced house to a sustainable heating system, involving the replacement of fossil light fuel oil with a combination of an energy-efficient air-to-water heat pump and a solar photovoltaic system.

Base data for environmental impact calculations

Prior to the energy system modernization, annual consumption for the terraced house complex was:

- 10,000 liters of light fuel oil for heating
- 3,215 kWh of property electricity for non-heating purposes (calculated average based on measured consumption from 2022–2025).

Following the installation of the air-to-water heat pump, electricity consumption is projected to increase, resulting in the following annual breakdown:

- 20,000 kWh for the air-to-water heat pump
- 2,800 kWh for the housing company's property electricity
- 12,000 kWh for the combined electricity consumption of the six apartments

Annual solar power generation is approximately:

- 11,500 kWh of which
 - the housing company can utilize 5,750 kWh (assumed 50 % self-consumption rate)
 - electricity distributed to residents (assumption: 50 kWh/month over 7 months across 6 apartments) 2,100 kWh
 - 3,650 kWh sold to the grid

Purchased and sold electricity differ in price; while sales are based on the spot price, electricity companies often deduct brokerage fees from the purchase price. Depending on the electricity company, this typically ranges from 0 to 0.3

cents/kWh. [2] The calculations for the selling price of surplus solar electricity utilized the FinSolar calculator's average figure of 0.04 €/kWh, which accounts for the fact that solar electricity sales are concentrated in the summer season.

The price of purchased electricity is 0.14 €/kWh for general distribution and 0.13 €/kWh for capacity-based distribution. Emission factors for various energy sources are presented below (Table 8). The cost price of the oil is based on the price at the time of writing (1.50 €/liter).

Table 8. Emission factors for energy sources (tCO₂/GWh)

Energy source	Emission factor (tCO ₂ /GWh)	Source
Oil heating	242,0	https://stat.fi/fi/tilastot/tietoa-teemoittain/kasvihuonekaasuinventario/polttoaineluokitus
Electricity	45,0	https://www.motiva.fi/tietopankki/energiankaytto-suomessa/co2-paastokertoimet
District heating	115,0	https://www.motiva.fi/tietopankki/energiankaytto-suomessa/co2-paastokertoimet/
Heat pump	12,9	
Solar energy	0,0	

Emissions and financial calculations for the energy system modernization of a terraced house complex

An integrated assessment of the environmental and economic impacts resulting from modernization of the energy system of a six-unit terraced house complex (switching from oil heating to a heat pump and on-site solar power) demonstrates that the changes lead to significant reductions in both emissions and costs.

Prior to the energy system modernization, total annual emissions amount to 24.34 tCO₂; following the modernization, they stand at 0.92 tCO₂. Thus, emissions are reduced by approximately 96 % compared to the original levels.

A cost comparison shows that total annual costs are 15,463 € before the modernization and 4,573 € after it. Consequently, energy costs are approximately 70 % lower than the original figures.

A more detailed breakdown of the figures associated with the energy system modernization is provided below (Table 9).

Table 9. The impact of the energy system transformation on emissions and the economy

Before	consumption/year	unit conversion GWh	emission factor (tCO₂/GWh)	Emissions, tCO₂/year
light fuel oil (l)	10000	242,0	24,20	15000
purchased electricity (kWh)	3215	45,0	0,14	463
Total			24,34	15463
After the modernization of energy system	consumption/year	unit conversion GWh	emission factor (tCO₂/GWh)	Emissions, tCO₂/year
purchased electricity for the housing company (does not include AWHP consumption)	2800	45,0	0,13	380
AWHP	20000	12,9	0,26	2712
residents purchased electricity (total of 6 apartments)	12000	45,0	0,54	1627
housing company's own electricity production	11500	0,0	0,00	
electricity for the housing company's own use (50 %)	5750	0,0	0,00	0,0
Distribution of excess electricity production to shareholders/residents per property (assumption: 50 kWh/month in a total of 6 apartments over 7 months)	2100	0,0	0,00	
electricity sales to the grid	3650	0,0	0,00	146
Total			0,92	4573
Emission reductions and cost savings after energy system change			24,42	10 890



Figure 6. Savings from emission reductions. Source: Michele Henderson / Unsplash

Decommissioning and recycling of a solar PV system at the end of its life cycle (WEEE)

A solar photovoltaic system typically has a lifespan of 25–30 years; its sustainability depends on managing the entire lifecycle, ranging from design and operation to the responsible decommissioning and recycling of the equipment.

Solar PV system components fall under the scope of WEEE (Waste Electrical and Electronic Equipment) recycling. In accordance with producer responsibility regulations, manufacturers and importers are responsible for organizing collection and recycling. Decommissioning follows the WEEE Directive and national waste legislation, both of which mandate high rates of material recycling and recovery.

When a solar PV system reaches the end of its service life or is replaced, dismantling is carried out in a controlled manner, following these steps:

1. **Electrical disconnection:** Dismantling is performed by a qualified electrical professional. The system is disconnected from the electrical grid, and safety on the direct current (DC) side is ensured. Solar panels generate voltage when exposed to light while connected; therefore, special care is taken when handling DC cabling.

2. **Mechanical dismantling and roof condition inspection:** Panels, mounting systems, and cable routes are systematically dismantled from the roof in compliance with structural and occupational safety regulations. The condition of the roofing material is inspected at the mounting points, and any necessary sealing or repair work is carried out immediately.
3. **Removal of the inverter and electrical components:** The inverter, safety switches, and cabling are removed from the electrical areas for separate sorting.

The management of the system's end-of-life phase adheres to the following principles of responsibility and the circular economy:

- **Utilization of producer organizations:** During dismantling, it is ensured that panels and inverters are delivered to official WEEE (Waste Electrical and Electronic Equipment) collection points or to collection points managed by authorized producer organizations.
- **Assessment of reuse potential:** If the system is decommissioned before the end of its technical service life (e.g., due to roof renovation), the operational condition of the panels and inverter is assessed. Equipment in working order may be sold or released back onto the market.
- **Documentation and waste summary:** A waste report is prepared for the dismantling project, detailing the quantities of WEEE and metal scrap generated, as well as their final processing locations. This ensures the housing company's environmental responsibility and compliance with sustainability reporting requirements.

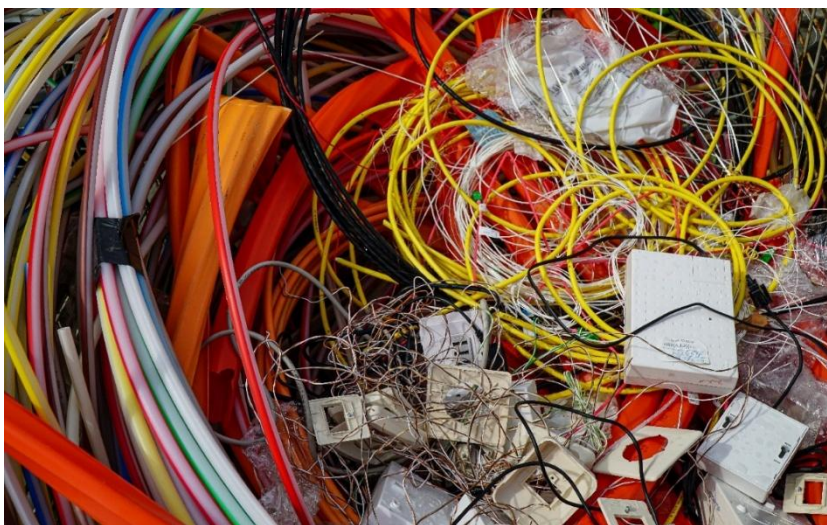


Figure 7. Cables. Source: Michael / Pexels

Conclusions and reflections

Key results and figures from Marttila's sustainability plan summarized

Economic sustainability

A solar PV system has a lifespan of approximately 25 years, a factor worth considering when evaluating the investment. A solar energy community and system modelled for a six-unit terraced houses complex in Marttila could generate around 11,500 kWh of solar energy annually. Half of this output (5,750 kWh) would be used for the housing company's own consumption needs, while the remaining half would be split between resident use (2,100 kWh) and sales to the grid (3,650 kWh). The investment cost for the system is 12,000 €. Calculated over a 25-year period, the Levelized Cost of Energy (LCOE) for the solar PV system is 8.3 cents/kWh, which is lower than the cost of electricity purchased from the grid (approximately 13–14 cents/kWh). The discounted payback period (DPBP) for the system falls between years 11 and 12. Savings in energy costs over the system's lifespan vary significantly depending on future electricity price increases. Roughly estimated, the savings over 25 years are:

- approximately 29,000 € in total, assuming no price changes
- approximately 42,500 € with a 3 % annual price increase
- approximately 85,000 € with an 8 % annual price increase.

Technical sustainability

From a technical perspective, the need to replace the inverter after approximately 10–15 years must be considered. When selecting a system, it is advisable to compare different service providers and *A scoring matrix for the request for tenders* (Table 6). Furthermore, fire safety and regular maintenance are integral to technical sustainability.

Social sustainability

Transitioning the energy system from fossil-based to renewable and sustainable alternatives promotes housing equity and combats energy poverty within the municipality's housing stock. Energy-efficient systems keep property operating costs low, thereby accelerating the payback period and ensuring that any rent increases remain moderate.

In the case of a solar energy community, residents also benefit from the credit calculation for solar energy production.

Environmental sustainability

In terms of environmental sustainability, the primary goal was to determine the impact of the energy system modernization on emissions, but at the same time, the aim was to calculate how this impact would be reflected economically in energy costs. When the energy system is switched from oil heating to a combination of an air-source heat pump and a solar photovoltaic system, emissions decrease by approximately 96 % annually, and energy costs decrease by approximately 70 % annually. The change is therefore significant.

Recommendations for energy-efficiency renovations: the threefold impact of technical, economic, and environmental sustainability

Modernization of a property's heating system and acquiring a solar PV system are not separate measures but rather a mutually reinforcing combination. Solar PV alone does not solve the issue of high winter heating costs; however, when combined with heat pump technology, the rate of solar self-consumption and the total return on investment can be maximized.

An energy system modernization is particularly worth considering for properties currently heated by fossil fuel oil or cost-inefficient direct electric heating. The heating system being replaced determines both the technical solution to be selected and the method for optimizing the benefits derived from solar PV.

The impact of the existing heating system on solar PV integration

1. Oil-heated properties (hydronic heating)

Technical solution: Replace the oil boiler with an air-to-water heat pump (AWHP) or a ground-source heat pump system connected to the existing hydronic distribution network.

Solar PV integration: The heat pump shifts space heating and domestic hot water production to an electric system. This increases the property's electricity consumption, including during the March–October period when the AWHP produces domestic hot water. Solar electricity can be fed directly to the heat pump, raising the self-consumption rate of the panels to a very high level (50–70 %) and directly reducing the amount of electricity purchased from the grid.

Benefit: Eliminates dependence on oil entirely and protects the housing company against the rise in heating oil prices resulting from the upcoming EU Emissions Trading System (ETS2).

2. Properties with direct electric heating (no hydronic distribution system)

Technical solution: Implement a decentralized energy efficiency upgrade by installing individual air-source heat pumps (ASHPs) in each apartment to reduce the load on direct electric radiator heating. Domestic hot water continues to be heated by individual electric water heaters.

Solar integration: Air-source heat pumps reduce the electricity consumed for apartment heating. Peak solar generation (in summer) aligns perfectly with the cooling demand of the ASHPs and the base-load consumption of the domestic hot water heaters. The output from the housing company's shared solar power plant can be distributed to residents under energy community legislation (net billing/allocation).

Benefit: A low-threshold, low-investment solution that delivers immediate savings on residents' electricity bills.

Synergy of a threefold impact

By combining a heating system upgrade with solar power, a housing company achieves synergistic benefits across key areas of sustainability:

Technical sustainability: The heat pump utilizes surplus electricity from solar panels to heat domestic hot water and cool apartments precisely when solar generation is at its peak.

Economic sustainability: Selling solar electricity to the grid yields low returns because the savings associated with electricity tax (approx. 2.92 cents/kWh) and distribution fees (approx. 4–6 cents/kWh) are lost. A high self-consumption rate maximizes savings on distribution fees and taxes, shortening the solar power system's payback period by approximately 1.5–2.5 years.

Environmental sustainability: Moving away from fossil oil eliminates direct local CO₂ emissions. From spring through autumn, the additional electricity required by the heat pump is generated largely without emissions by the company's own solar power plant.

Sources

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