Solar Mounting Product Scenarios

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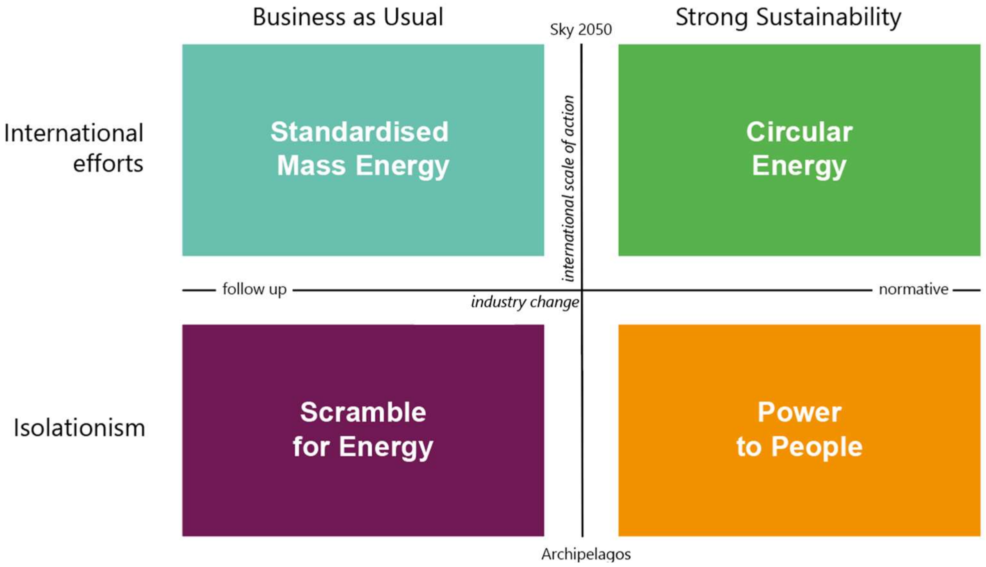
Summary

This thesis explores the future of the solar mounting industry by constructing and assessing four product-scenarios. The goal was to assess how these scenarios could influence the development of a climate neutral solar mounting product by 2040.

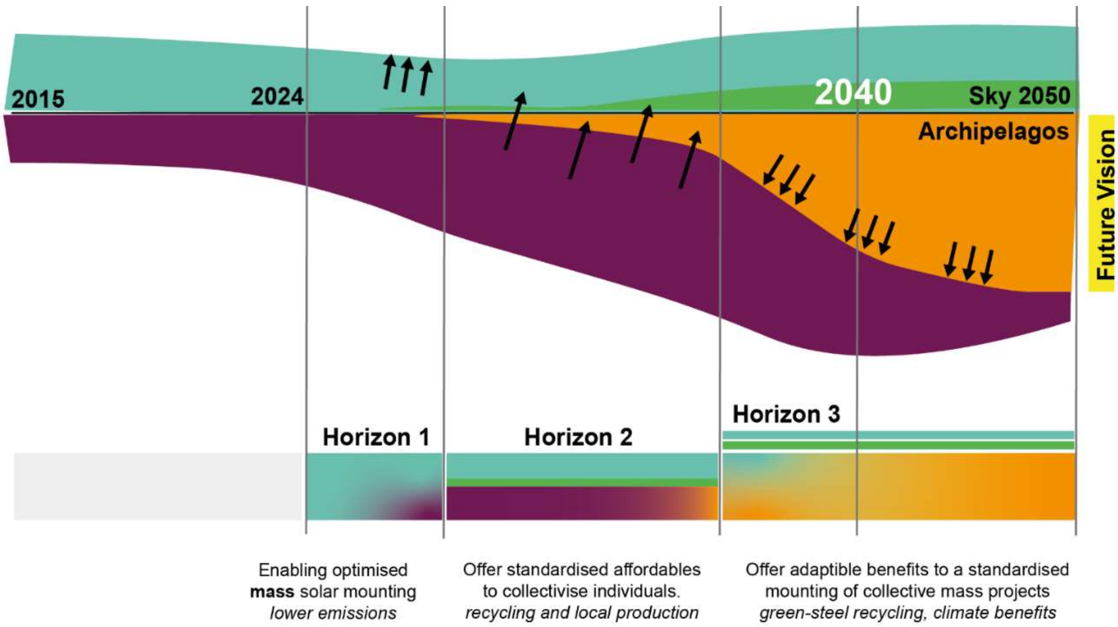


- Standardized Mass Energy (SME): This scenario envisions a future where solar energy systems are mass-produced and standardized to efficiently meet global energy demands. The focus is on uniform, large-scale, high-efficiency solar mounting products that can be deployed rapidly. Governments and large corporations drive this scenario, prioritizing speed and efficiency in installation, while achieving climate neutral products by application of green steel.
  If international cooperation remains strong and the focus on large-scale infrastructure continues. Stakeholder assessment indicates that this scenario is possible due to current market trends favouring scalability and cost-efficiency. But consolidation might eliminate their margins.
- Circular Energy (CE): This scenario prioritizes sustainability through a reuse-system for solar panels, aligning with the circular economy principles. Solar mounting services create modular, reusable systems, being climate neutral in prioritising reuse and minimising green steel production. The spatial arrangement alternates solar with green roofs and urban gardens, promoting local energy distribution. While this scenario is desirable, it faces challenges in market acceptance and requires significant shifts in political and economic frameworks. Stakeholder assessment suggests elements of this scenario could unfold, if there is a strong policy push towards circular economy from society.
- Scramble for Energy (SfE): This scenario envisions a chaotic and competitive market driven by geopolitical tensions and the need for energy security. Solar products vary in quality, with customers prioritizing affordability and speed over sustainability, leaving no securance of a climate neutral product. The spatial arrangement is also chaotic, leaving no room for nature, due to the pressures of energy scarcity and instability. The stakeholder assessment reveals that this scenario is highly likely in the near future, particularly if global energy markets become more fragmented and nations keep prioritising self-sufficiency over collaboration.

- Power to People (PtP): This scenario focuses on social equity, with solar energy being distributed to balance industry and citizen needs. With international failure in climate action, the emphasis is on domestic production and local community empowerment. Solar installations are integrated with multifunctional benefits as climate adaption or water-management, creating collective responsibility. While this scenario is highly desirable for sales, it demands significant restructuring of industry practices and societal norms. Stakeholder assessment indicates this scenario could unfold (after SfE has,) if there develops a societal movement towards communal energy equality and local wealth, supported by progressive policies.

Scenario	PV products (Table 4)	Mounting (Table 4)	Clients	Sustainability (Figure 15)	Spatial arrangement (Figure 16)
Standardised Mass Energy	Uniform, high-efficiency, large-scale panels	Rapid deployment, standardized, robust systems	Governments, large corporations; bulk purchases	Low-carbon materials, optimized production processes	Extensive solar fields, mass rooftops, centralized infrastructure
Circular Energy	European production, Durable, modular, recyclable	Modular, easy to disassemble and repurpose	Environmentally conscious businesses; lifecycle-focused purchases	Recycled materials, reuse focus, circular economy principles	Minimal use of roofs, local and grid supply, energy conservation
Scramble for Energy	Varied quality, all sizes, mix of high-performance and low-cost panels	Flexible and chaotic, adaptable to various environments, DIY-friendly	Diverse clientele; price-driven, immediate availability purchases	Minimal focus on sustainability, driven by cost and necessity	Chaotic, diverse locations, infrastructure struggles
Power to People	As import batches, different production originations	Customisable to tenders, locally-supporting products & installations	Local communities, cooperatives; socially motivated purchases, governmental tenders	Local sourcing, minimal impact, easy maintenance	Multifunctional spaces, decentralised, integration with greenery and community spaces

The overview above demonstrates the product-system per scenario, as designed for.
The scenarios provided for a roadmap construction for the solar mounting company Sunbeam. By understanding potential futures, Sunbeam can strategically navigate the evolving mounting industry, balancing immediate product-demands with product interventions inspired by a long-term climate neutral vision. The roadmap allows Sunbeam to lead with a strategy of collaborations and products that stimulate envisioned system development.



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1. Introduction

Solar energy plays a key role in the global transition towards renewable energy, making it essential for achieving the Paris Climate Accord's goals. To maximize the potential of solar energy, effective mounting systems for attaching photovoltaic (PV) panels to various surfaces, such as roofs and facades, are crucial. However, the path to a climate-neutral European Union by 2050 involves more than just installing solar capacity; it also requires that the supporting products, both electronic and mechanical, be developed into climate-neutral applications.

This graduation project aims to support the development of future climate-neutral solar mounting products.

1.1 Design Brief

Graduation Company: Sunbeam

Sunbeam, a producer and supplier of solar panel mounting solutions in the Benelux and beyond, was founded in 2011. The company has become a significant innovator and sustainable producer of mounting systems for both pitched and flat roofs. By consistently minimizing the CO2 impact of its products and compensating for remaining emissions, Sunbeam has achieved full CO2-neutral certification for its products since 2020.

While Sunbeam's voluntary emissions compensation underscores its leadership in solar mounting sustainability, the company recognizes that compensation is only a temporary solution. Sunbeam's goal is to achieve true climate neutrality in its products by 2040. To this end, the company plans to gradually optimize its current product portfolio while also exploring alternative product systems with actual climate neutrality potential. Initial explorations have included reusing wooden beams and utilizing low-quality recycled plastics.

However, no comprehensive research has yet been conducted into the broad production possibilities and market needs for a climate-neutral solar mounting system that would be viable in 2040.

Climate Neutral

Sunbeam's ambition to achieve climate neutrality by 2040 is focused on eliminating the need for emissions compensation. The EU has also introduced a ban on using the term "climate neutral" for claims based on offsetting (Kurmayer, 2023). So, what constitutes a climate-neutral product?

According to the IAAS (2015), climate neutral '*describes a state in which the activities of a product'* (or other identity), '*result in net-zero climate impact from greenhouse emissions. The net-zero implies that the activities must release no greenhouse gases or the warming that results from the greenhouse gases they still release after reducing emissions as much as possible must be balanced out by CO2 sequestration'*.

Such definition seems in line with the EU directive, stating '*Such claims can only be allowed when they are based on the actual lifecycle impacts of the product in question, and not based on greenhouse gas emissions offsetting outside the product's value chain, as the former and the latter are not equivalent'* (EU Committee IMCP, 2023).

Translated to Product Design, a ***climate neutral product*** is designed to be produced either 1) without using any emitting materials and processes, 2) with emitting materials and processes of which emissions are captured/stored in the process or 3) with an internal neutralising mix of emitting and compensating materials and processes (through positive capture/storage).

Formulating the Design Brief

Designing a climate-neutral solar mounting product for Sunbeam by 2040 depends on numerous uncertain developments including markets, technology, geopolitics and societal values. it was never really designed for. This project will use scenario construction to design such a product. Formulating the design brief, as to the

Design of future product-scenarios for a climate neutral solar-mounting system on flat roofs in 2040.

1.2 Scenario Theory and Hypothesis

This section explains why I combined scenario construction with product design to create 'product-scenarios.' For scenario construction, I utilized the 'Industry Scenarios' method and adapted it to a design practice (paragraph 1.3).

Why product-scenarios?

As described by Fahey and Randall (1998), 'scenario learning is useful to be adopted by the organisation if it has reason to believe that:

- It's future business context will be significantly different from that prevailing today.
- A set of strongly differentiating alternative futures for the operating environment, could be in consideration.
- Although shaped by trends, surprises may significantly affect the industry operated in.'

In the solar industry, all these factors are highly relevant. Climate change and the internation energy market will greatly influence the business context. The development of new PV technology and potential spatial integration options for solar will profoundly influence the industry's future. And at last, the political choices on funding and investing in solar can fluctuate and surprise the markets, as seen before (Ministerie van Algemene Zaken, 2024).

From my experience, production industry managers often overlook long-term scenario thinking and 'mistakenly limit the scope and domain of scenarios' (Fahey and Randall, 1998). Or they construct a personal 'most likely future', avoiding exploration. They may view scenarios as speculative, never precise predictions of the future.

Product-scenario's hypothesis

A well-constructed scenario projects a future business context in which a company's products could exist. It serves as a tool to explore potential futures, allowing better preparation for the business and product aspects within those futures (Fahey & Randall, 1998). Scenario thinking can also influence strategic decisions in research and development (R&D). By integrating scenario thinking with product design, companies can strategically develop future products that might not have been otherwise considered.

According to Fahey and Randall (1998), an effective scenario should challenge and surprise managers, stimulating decision making through relatable views. For product-industry managers, *exploring scenarios through product development* could be beneficial because product design offers a clear and tangible representation of future possibilities.

Strategic Transformation as Ambitious Leader

The 'Adviesraad voor wetenschap, technologie en innovatie' (Bruins et al., 2023), explains the need for moving from optimisation to transformation. While optimisation is only improving from the now, transformation requires a more visionary and exploratory approach. By employing long-term scenarios and developing a future vision, my research could provide Sunbeam with a <u>design that serves as both a compass and magnet for this transformation</u>. Sunbeam aspires to lead the industry towards a climate-neutral future by inspiring transformations with this design.

Hypothesis

I propose **that scenarios and product designs can mutually reinforce each other's success and realization**. Designing a product for a specific future scenario enables the exploration of desirable directions for R&D and business strategies. The resulting strategic projects, in turn, act as market interventions (Figure 1) that facilitate the development and realisation of the preferred direction for both product and system.

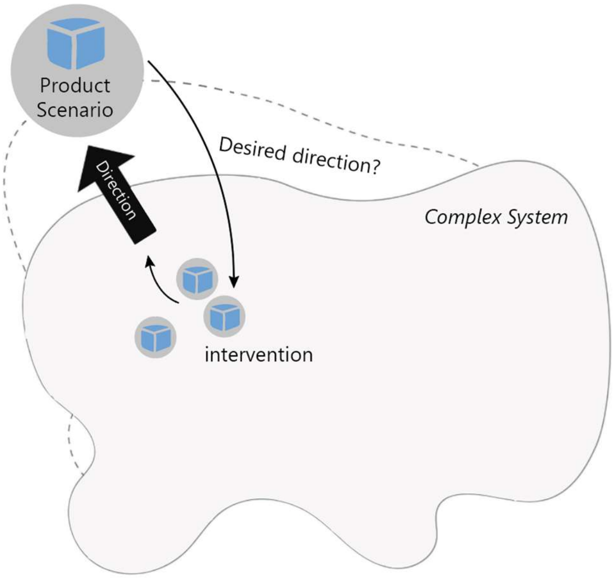


Figure 1: Adapted from Van der Bijl-Brouwer, 2024. The "Product Scenario" serves as a conceptual model that identifies desired directions for a complex system. By designing and implementing interventions based on this scenario, the product development process can guide the system towards that desired direction. Essentially, the product scenario not only predicts but also actively shapes the path the system takes, reinforcing the mutual success and realization of both the scenario and the product itself.

Industry scenarios

The solar mounting industry holds the role of providing the solar industry and energy market as a whole, and will transform its mounting systems and supply with it. To develop products that fit this future system-context, I explored the overall solar industry through the scenario construction method regarding 'industry scenarios'.

Fahey and Randall (1998) outline four key purposes for constructing industry scenarios, all of which are directly relevant to this project:

- Identifying plausible future states of an industry and the differences among them.
- Illustrating how each future state might evolve and mapping out the possible paths.
- Enhancing strategic thinking by uncovering unexpected market opportunities and threats, and illustrating competitive dynamics.
- Enabling an organization to anticipate necessary actions at every business level to succeed across various industry scenarios.

Fahey and Randall (1998) introduce a 'steps and questions' plan for constructing an Industry Scenario. Building on the process outlined by Fahey and Randall (1998), I adapted their industry scenario construction method specifically for this research project (figure 2). This adaptation resulted in six major design practices: setting the design brief, the future forward approach, the future backward approach, product scenario development, stakeholder assessment and future visioning & road mapping (paragraph 1.3).

1.3 Method and Approach

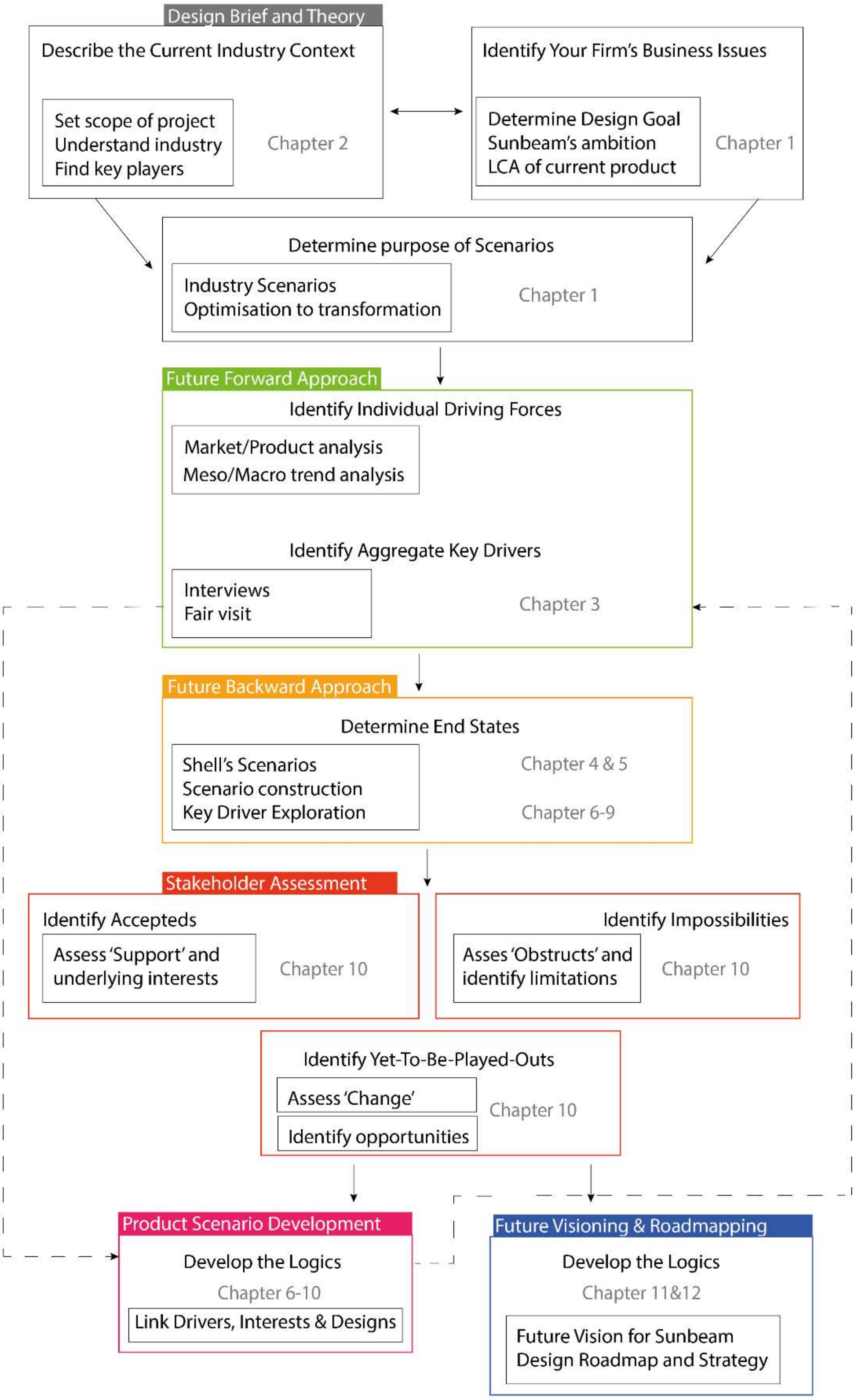


Figure 2: Schematic of my applied Product Scenario Construction process, adapted from Fahey and Randall's (1998) 'Constructing and Industry Scenario: Steps and Questions'.

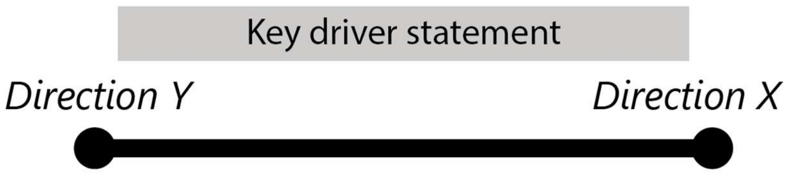
Setting the Design Brief

The determination of the issues of my firm 'Sunbeam' and of the purpose of the scenarios is done by the creation of the Design Brief (Chapter 1) of my graduation project. In Chapter 2, I further describe the scope of the project. By doing this graduation project at Sunbeam, I have used their knowledge, insights and contacts to personally develop an understanding of the context of this solar mounting industry.

Future Forward Approach

For the step of identifying the driving forces of the industry, I applied a so called 'future forward approach' (Fahey and Randall, 1998). This method extrapolates the 'now' via an analysis of possible events, trends and developments at micro (product), the meso (industry-specific) and macro (broader energy environment) levels. By identifying the main key drivers to the scenario's context, you would be able to plot future scenarios linking to certain changes and constants.
In my research project, a **key driver** contains of two elements:

- **Key driver statement:** It describes a developing factor that strongly influences the future of the solar mounting industry ('Key driver statement')
- **Area of potential development:** Describes the reasonable field of potential directions this factor could develop into (the line). It is explained through describing its extremes ('Direction X and Y').



Through extensive research on all three trend levels (Figure 3), in a process similar to the ViP-method (Hekkert et al., 2011), I found many relevant trends that appointed to eight overarching drivers (see Appendix B for process). These drivers, along with their potential development paths, are presented in chapter 3.

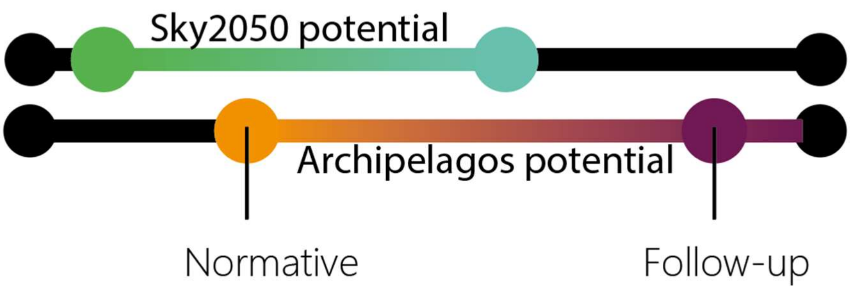
Trends & Development analysis:	Scale	
Solar mounting product perception	Products	Micro
Solar-mounting products (in the market)	Products	Micro
Sales and stakeholders in solar mounting	Industry	Meso
Human Capital in the installations market	Industry	Meso
Feasibility of Dutch roofs for solar mounting	Industry	Meso
PV production and technology	Industry	Meso
National/EU solar capacity ambitions	Energy	Macro
Sustainable Materials & Production	Energy	Macro
International climate policies & economics	Energy	Macro

Figure 3: List of topics researched in trend & development analysis, labeled per scale and micro, meso and macro level. Further explanation in (Appendix B)

Future Backward Approach

To complement the forward-looking analysis, I applied the 'future backward approach' to define the end states of the scenarios (chapter 4 and 5). This approach, also drawn from Fahey and Randall (1998) is 'To show what would have to happen for each end state to emerge from the present'.

For this project, I used Shell's "Energy Security Scenarios" (Shell International Limited, 2023) as a foundation for defining potential end states of the energy industry. The Sky2050- and Archipelagos-scenarios served as a framework for refining the possible directions of my key drivers:



For each energy-industry end-state (being a Shell scenario), I constructed a direct subsequent scenario for the solar mounting industry. With directions for my key drivers **following-up** business as usual (Blue for Sky2050 and Purple for Archipelagos). These scenarios are:

- Standardised Mass Energy (follow-up, Sky2050)
- Scramble for Energy (follow-up, Archipelagos)

But within the same Shell scenarios, the broad context of the energy industry creates room for interpreting alternative developments of the key drivers on the level of solar mounting. As Sunbeam ambitions 'climate neutral products in 2040', I explored alternative perspectives useful for an improved sustainable direction (including climate neutral potentials).

As climate neutrality is not always feasible, I reconstructed the best overarching sustainable scenario. This **normatively** scenario, setting new norms, is constructed just within the explored boundaries and limits of the key drivers' potentials in the Shell Scenarios (Green for Sky2050 and Orange for Archipelagos). The normatively created scenarios, pushing sustainability are:

- Circular Energy (normative, Sky2050)
- Power to People (normative, Archipelagos)

With eight key drivers and four scenarios, these scenarios can be explained through many matrixes, but the core values of the scenarios are presented over the axis of 'international scale of action' and 'industry change'. Just as in the ViP-method (Appendix B), these axis are presented in the matrix in Figure 4, resulting to four differing world views (scenarios).

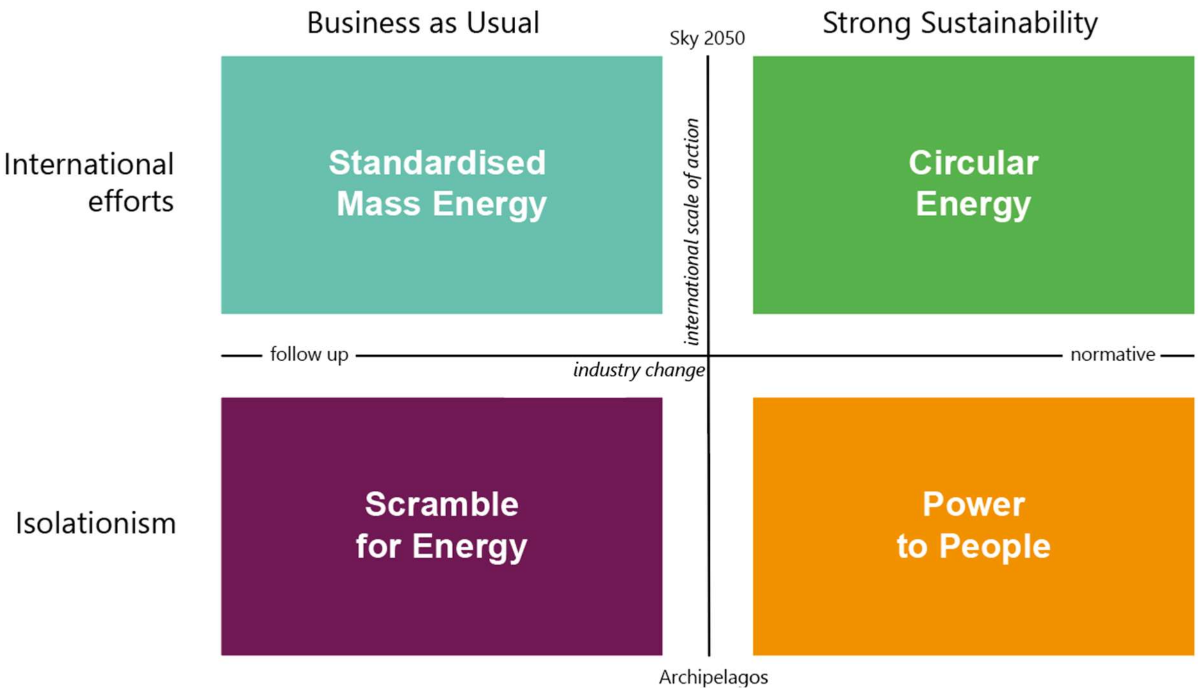
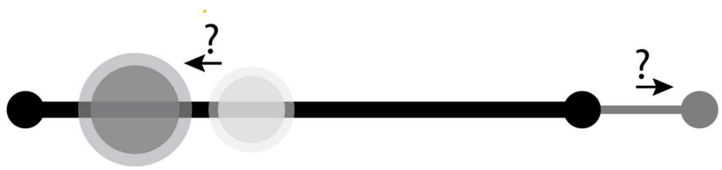


Figure 4: The four constructed end-states for the solar industry and their core values. Within Shell's two Energy Security Scenarios, one end-state following up Businuss as Usual (SME for Sky2050 & SfE for Archipelagos) and one end-state pushing limits for sustainability (CE for Sky2050 & PtP for Archipelagos)

Product Scenario Development

To integrate product design into scenario development, I added an iterative design process to Fahey and Randall's model. By including the iterative approach of a design cycle to scenario development, the product design allowed for a more tangible exploration of end-states and interests.

This means that the product design process supported the research and iteration around alternative developments of key drivers in the future forward approach, and around interests and combinations of key drivers in the future backward approach.



The final result of this design process are the four constructed scenarios (as in Figure 4), presented with a product and service design, a supply chain and sales model (Chapter 6 till 10).

Stakeholders Assessment

Once the scenarios were developed, I conducted a stakeholder assessment. By facilitating discussions with industry stakeholders over a tangible product design, I was able to identify what, to their market interests, were the yet-to-be-played-out, accepted and impossible aspects of a scenario.

The stakeholders' future interest in such scenario aspects, could determine whether, for the related key drivers, development will be supported, obstructed or needs changing. Figure 5 presents a visual representation of how the stakeholder interests result into insights on the development of the key drivers.

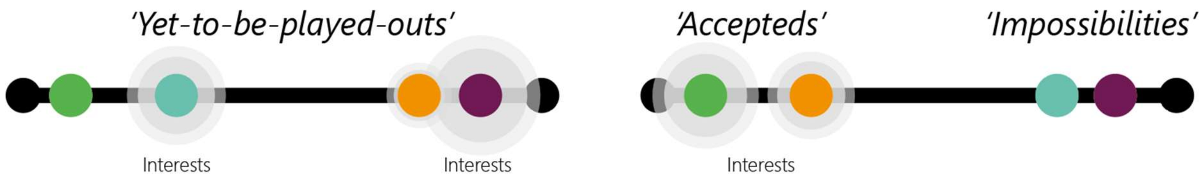


Figure 5: Stakeholder interest influencing the likelihood of a development of a key driver. If several scenario outcomes are of interest, it can be yet-to-be-played-out. But if interests in certain scenarios are clearly leaning into a certain direction, it becomes accepted. The other becomes 'impossible'.

Future Visioning & Design Roadmapping

Based on the stakeholder assessment, I identified the most likely development of the industry. Matching to alternative interests, I crafted a Future Vision for Sunbeams, which ambitions its most desirable, viable, and feasible position in the future industry.

To create a roadmap towards this Future Vision, I applied a time pacing strategy (Simonse, 2023). This strategy allows Sunbeam to adapt to emerging scenarios while strategically positioning itself for succession of the Future Vision. By planning design and business efforts around the emerging scenarios, Sunbeam can stabilize its market position and potentially accelerate the development of preferred outcomes, within its influence.
As strategic products can act as interventions to create new value propositions, belief systems or stakeholder interests and influence key drivers.

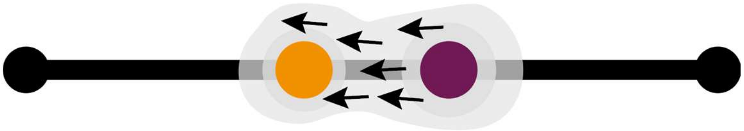


Figure 6: A company's strategic interventions can shift interests towards the preferred development (orange) of the key driver, while also answering current market interests (purple).

This time pacing strategy is implemented in the roadmap for Sunbeam. But as key drivers will change in expected development, it is made as an 'living document'. The roadmap is made in Excel, as to allow for accessible recurring updates and reinterpretation of new developments.

2. Scope of Project: Flat Roof Mounting

Solar mounting products are structural systems designed to secure PV products to various surfaces, including roofs, floors, and other (dynamic) objects. Today, PV systems are installed on a wide range of surfaces such as roofs, facades, vehicles, infrastructure, grasslands, and waters —essentially any flat surface exposed to sunlight.

For this study to remain feasible within the timeframe of a graduation project, I will focus on solar mounting for flat roofs in an east-west orientation. This focus is based on Sunbeam's significant market share and expertise in flat-roof mountings. Developing a design within this existing product portfolio is the most practical approach, as exploring other mounting situations would require a more extensive design process.

Nevertheless, to design a future product scenario effectively, I will also explore broader potential markets, user contexts, and production technologies for solar energy. The growth potential of alternative solar energy products will influence our future product scenarios for flat-roof mounting.

2.1 Minimal Program of Requirements

Figure 7 provides an overview of a typical flat-roof mounting solution in east-west orientation.

The figure outlines the core elements and functions of a flat-roof solar mounting system. However, many additional functions and requirements are essential for proper solar mounting. In Appendix A, titled 'Minimal Program of Requirements,' I have detailed all the essential requirements and desired features for a safe and functional flat-roof solar mounting system. These minimal requirements include those derived from external conditions, physical laws, and safety standards often outlined in norms. These requirements must be met, regardless of design specifics. Additionally, I include efficiency-related wishes, as ignoring these aspects could significantly reduce energy or installation efficiency to unacceptable levels unless alternative designs address the underlying issues.

In Table 1, I summarize the minimal requirements for solar mounting and how Sunbeam's products meet these criteria.

Requirement	Current Fulfilling (Sunbeam)	Explanation (Sunbeam)
Installation		
To install on a roof	16 cm spacing (between structures)	Food width, to be installed by simple-trained installers
Structure (weight)		
To enable different roofs	15 - ≥20 kg/m2 weight adjustment	Enable some roofs with low weight + additional ballast or interconnecting structural weights
Performance (of PV)		
To capture sunbeams effectively	10° angle towards sun	Optimal fixed angle, preventing soiling
Mounting (of PV product)		
Provide mounting of PV products	Panels of several sizes, 50mm clamps	Size segmentation per customer segment, standard clamps
Materials		
Resist weather circumstances	Coated Steel	UV, Corrosion resistance material
Secure		
Hold against lifting wind forces	Deflecting design + Ballast / Anchoring	Minimal cast shadow, soil cleaning, performance
End of life		
Sustainable handling of PV product	Disassembling of PV and structure	The pv panels can be separated for proper waste management
Safety		
Secure installation + grounding	Project planning with trained installers	Demand for proper fixation, by panel producer and insurance

Table 1: Summary of Minimal List of Requirements

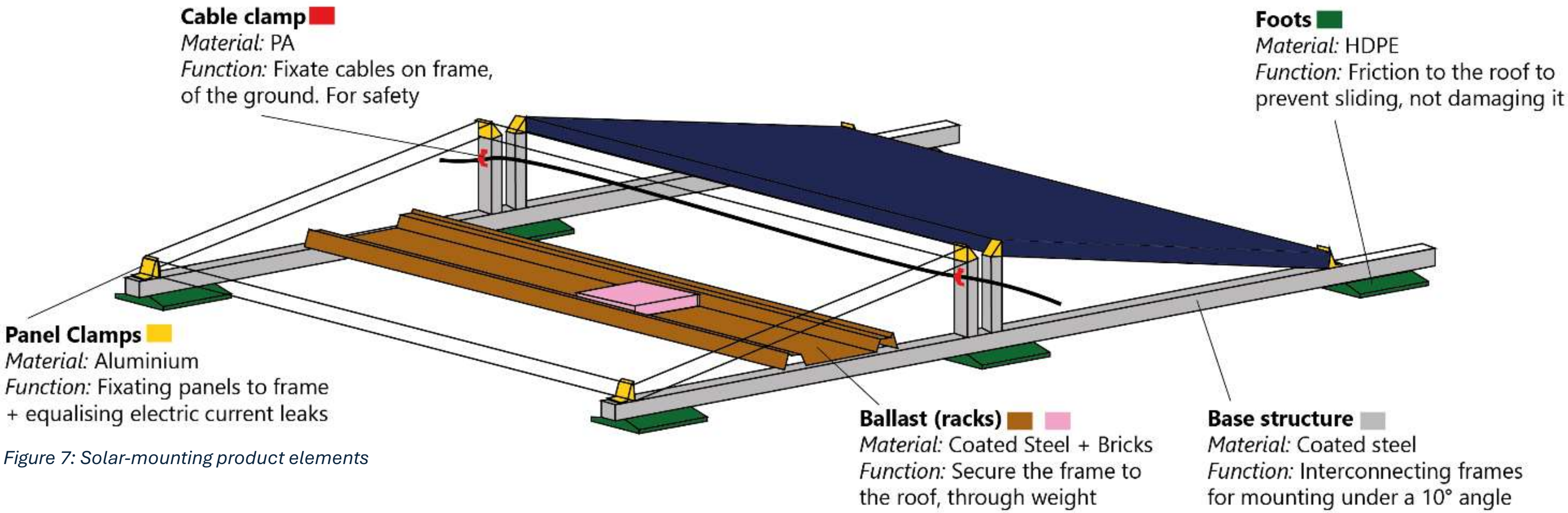


Figure 7: Solar-mounting product elements

2.2 Climate Impact and LCA

From my graduation company comes an extended LCA on a flat-roof solar mounting system in the east-west orientation. The LCA, officially certified, calculates the Environmental Cost Indicator (MKI) to communicate the environmental impact.

Outcomes of the LCA
The LCA reveals that over 95% of the MKI impact occurs during the material extraction and production phases, with residual contributions from transport, installation, and End-of-Life processes. But in an LCA, optimizing the End-of-Life phase, particularly through ensuring recycling, could partially offset the environmental costs incurred during production.

Among the materials analysed, steel accounts for 91% of the MKI impact, with aluminium contributing another 7%. The remaining impact is negligible due to the use of recycled non-ferrous materials. Notably, the impact of concrete, which is not included in the product sold by the company but is often used as ballast, is significant. The ballast should therefore be included in my search for a climate neutral product-system for solar mounting.

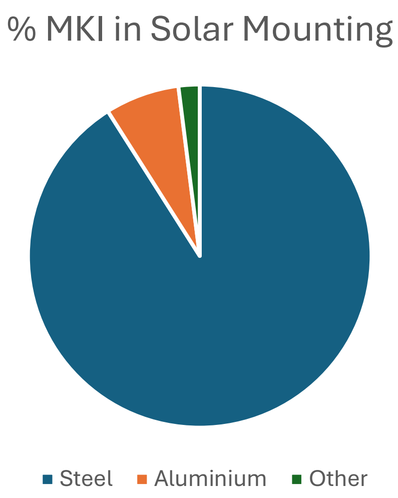


Figure 8: Relative MKI impact per material in Sunbeam solar mounting product

Designing a Sustainable Handling of PV
The supported PV products consist of several *critical raw materials*; ‘raw materials of high importance to the EU economy and of high risk associated with their supply’ (European Commission, n.d.). Therefore, properly maintaining, reusing and retrieving PV panels is an essential for obtaining ‘clean energy technologies’ in Europe. This sustainable handling of pv products becomes priority. The primary design objective is to ensure that the mounting system meets the minimal requirements .

Designing a Climate-Neutral Solar Mounting System
Given that the majority of environmental impact arises from steel, aluminium, and concrete, the second design objective is to redesign for a climate neutral product. Removing or replacing these materials in the product for materials of which emissions can be captured in the process or can be internally neutralised with compensating materials.

Once the climate neutrality of the product would be addressed, the next priority would be to reduce the climate impact of logistics and installation, making this the third sustainable design objective. But unless rising to a significant share in MKI’s through alternative product handling, this will be neglected in this research project.

PV

1. PV technology and products in market — *...affect mounting requirements*

Highly diversified PV products ↔ Standardised PV panels

In one potential future, in the search for unlimited options in solar energy production and alternative sustainable practices, many technologies and applications could be developed and exploited: creating an extreme variable or chaotic product portfolio.

In another potential future, the search for manageable energy systems, standardised installing procedures and predictable handling of supply results in standardised panels. The development of pv technology contributes to one mass-produced optimised solar panel type.

2. Production location of PV products — *...affect supply chain collaboration*

Significant European production ↔ International production and supply

In one potential future, the EU or market strongly stimulates European production and investments for the production of PV, so to gain a significant share in its own supply. The EU can control product quality/sustainability.

In another potential future, the growth of external PV supply destroys the European production, and spreads from China towards additional continents as Asia, Africa, South America or even the USA. The suppliers determine the offered products, collaboration is limited or absent.

PRODUCTION INDUSTRY

5. Geopolitical energy and product trading — *...affects material/industrial availability*

Specific trading clubs ↔ Free trade agreements

In one potential future, isolationism and independency-lead exclusion makes countries set up specific cooperations and international trading clubs to fulfill energy and production needs. The protected production industry complies to specific targeted material / energy availability

In another potential future, the approach for sufficient supply will come via stimulating the international free world market, driving a quantity of supply and options to be able to select. The production industry acts risk averse and is focused on cost price.

6. Improved Sustainability of Production — *...affects product's design for sustain.*

Managing Scarce Resources ↔ Circular Systems and Chains

In one potential future, the costs and availability of energy and material resources will stimulate the industry to produce locally, recycled or waste-based products, while economically driven, embedding circular aspects as energy conservation, reuse and minimising.

In another potential future, active efforts and policies against carbon emissions will stimulate embedding circularity on the most suited scale for a circular system, somewhere between integrated local reuse system up to pure controlled international recycling streams.

CONSUMER / SALES

3. Instalment projects and services — *...affect uniformity in method(s) of installing*

Collective Mass Instalment ↔ Individual Diverse Sales

In one potential future, the consolidation of the market results into a few all-round installing project developers with an expertise on optimising all parts of the installers supply chain. They would be installing on large project bases, in demand of collective customer segments.

In another potential future, the growth of the market stimulates a price suppression through a variety of customer needs and products, resulting in individually serving practices of installing, energy management and service. Mounting solar is not an expertise.

4. Answering energy needs in grid and price — *...affects modularity and compatibility*

Collective Energy Infrastructure ↔ Individual Energy Sufficiency

In one potential future, all renewable energy on roofs is producing for the grid. The solar energy is strategically located and sold openly within a system that matches supply and demand through public energy infrastructure, as is seen today. A solar field is build to its potential.

In another potential future, solar energy on roofs is produced for individual usage, by housings or businesses. Supply and storage is matched with their own energy needs and seen as an individual responsibility. Clients will be constantly adapting products and supply to their needs.

determines the LOCATION

7. Spatial lay-out priorities — *...affects mounting location & complexity*

Natural and Societal efforts ↔ Maximising solar on roofs

In one potential future, we are balancing solar with natural and social benefits so to improve the energy transition whilst improving nature and society. Mounting design deals with complex limifis for scarce land/roof space.

In another potential future, we are striving for a maximum coverage of roofs by smart constructure efforts on buildings and complex mounting systems. Society prioritises solar on all roofs, to unburden other locations.

8. Social acceptance and visibility sentiment — *...affects product look and feel*

Social Friction ↔ Proudly Visible

In one potential future, solar mounting development enables installing PV anywhere, in many matters of (luxurious) invisibility and price ranges, and becomes a visual representation of economic inequality.

In another potential future, the societal consensus is on striving for a maximum production of renewable energy and wealth, and widespread solar mounting solutions enable citizens to proudly participate in the energy transition. Design goes in function over aesthetic.

Figure 9: The eight key drivers are presented in four categories (vertical). Each key driver effects a relevant production/design/system aspect for solar mounting. The extreme potentials per driver are explained.

As phase:

Future Forward Approach
Identify Driving Forces Identify Key Drivers

3. Key Drivers of the Solar Industry

The production of solar-energy in the Netherlands has grown to over 21,17 billion kWh in 2023, around 37% of the renewable energy and 18% of the entire energy production (Centraal Bureau voor de Statistiek, 2024b). According to my research, the growth of this industry will be further effected by PV technology and production (paragraph 1&2), customer needs and sales (paragraph 3&4), geopolitical developments influencing industrial production (paragraph 5&6) and spatial impact and limitations (paragraph 7&8).

Eight Key Drivers
From my analysis at micro, meso, and macro levels (Appendix B) during the future forward phase, I identified eight key drivers that influence the solar mounting industry. These drivers, and the directions they might take, are illustrated in Figure 9.

3.1 PV Technology and products in the market

Our first key driver is the development of PV technology (Appendix C). Whether the market continues to favour standardized solar panels or shifts toward diverse solar products of varying sizes will significantly impact the required mounting solutions.

Standardised PV panels
As shown in Table 2, crystalline silicon (cSi) technology dominates the market, with rigid panels being the standard. Emerging technologies like perovskite in tandem applications may enhance energy performance, potentially maintaining rigid panels as the dominant high efficient solar product.

Highly diversified PV products
Alternatively, the advancement of perovskite technology, particularly in thin-film applications, could promote the adoption of more varied PV products such as flexible panels, bifacial panels, and BIPV products. These technologies, which become more and more competitive in performance and reduce reliance on critical materials, may gain market depending on global market needs for energy security and sustainability.

Table 2: The table summarizes the current and developing PV technologies, highlighting their structural details, efficiency, sustainability potential, and applications.

PV type	Structural details	Efficiency & performance	Sustainable potential	Applications & Development
Crystalline silicon cSi (standard) 95% of market	Rigid panels	21% 20-25 years	Mineral and metal intensive. ≤90% recyclable	PV panels, coloured, single cells in BIPV
Thin film Cd, a-Si, CIGS	Flexible sheets	10-15%, up to 17% ≤10 years	Lower energy, metal, mineral. Organic potential	Fixated on organic forms. PV on sticky roll
Perovskite (new, under development)	On flexible, semi-trans & rigid	~14-20%, up to 26%	No critical materials, up to 20x recyclable	In **tandem** within panels (to get ≤27%)

3.2 Production location of PV products

The second key driver is the development of PV production facilities and their locations in the world market (Appendix D). It affects supply chain dependency and control and so the potential for circular collaborations between PV and mounting producers.

Significant European Production

The EU's Solar Energy strategy aims to achieve 600GW of installed capacity by 2030, increasing demand for PV products. There have been suggestions for investments under the European Green Deal (SolarPower Europe, n.d.). However, the European production remains limited. Investments in perovskite technology could reduce resource dependency and stimulate European production, when dependencies and geopolitical tensions rise.

International production and supply

The exponential growth of PV production has only ever been underestimated (Sinke,2023). The figure below illustrates the heavy reliance on Chinese production, highlighting the need for strategic international production to secure supply chains. In Europe however, the lack of domestic cell and wafer production (Fraunhofer ISE, 2023), and potential mining locations limits our growth potential. So the EU likely remains depended on import from diverse regions.

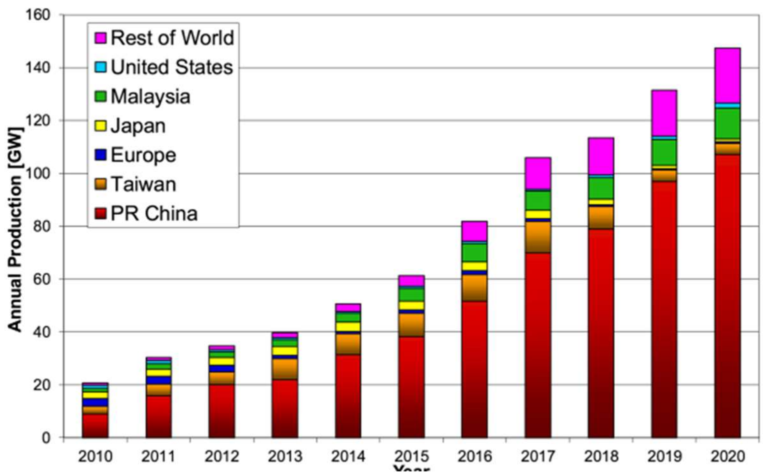


Figure 10: World PV cell/thin film module production from 2010 to 2020 (Jäger-Waldau, 2021).

3.3 Instalment projects and services

The third key drivers is the development of the installing and service practices supplied (Appendix E). Whether the industry moves towards collective mass projects by consolidated players, or further develops as individual free-market orders will affect product uniformity and installation expertise.

Collective Mass Instalment

For interviewed stakeholders (Appendix K), human capital shortages are a concern. This is prompting initiatives like the European Green Deal to stimulate training for skilled installers (SolarPower Europe, n.d). There is also a push that the expected growth of solar demands for standardized multi-purpose systems (TKI Urban Energy, 2022). And the first observed consolidation efforts show stakeholders position themselves as all-round service providers.

Individual Diverse Sales

The complex diversity of services — as project coordination, consulting and failure support— is reflected by how stakeholders variably mix the services they offer (Figure 11). The interview respondents explain (Appendix K) how cost pressures drive them to continuously change their services and products to the growing needs and choices of more individualising customers.

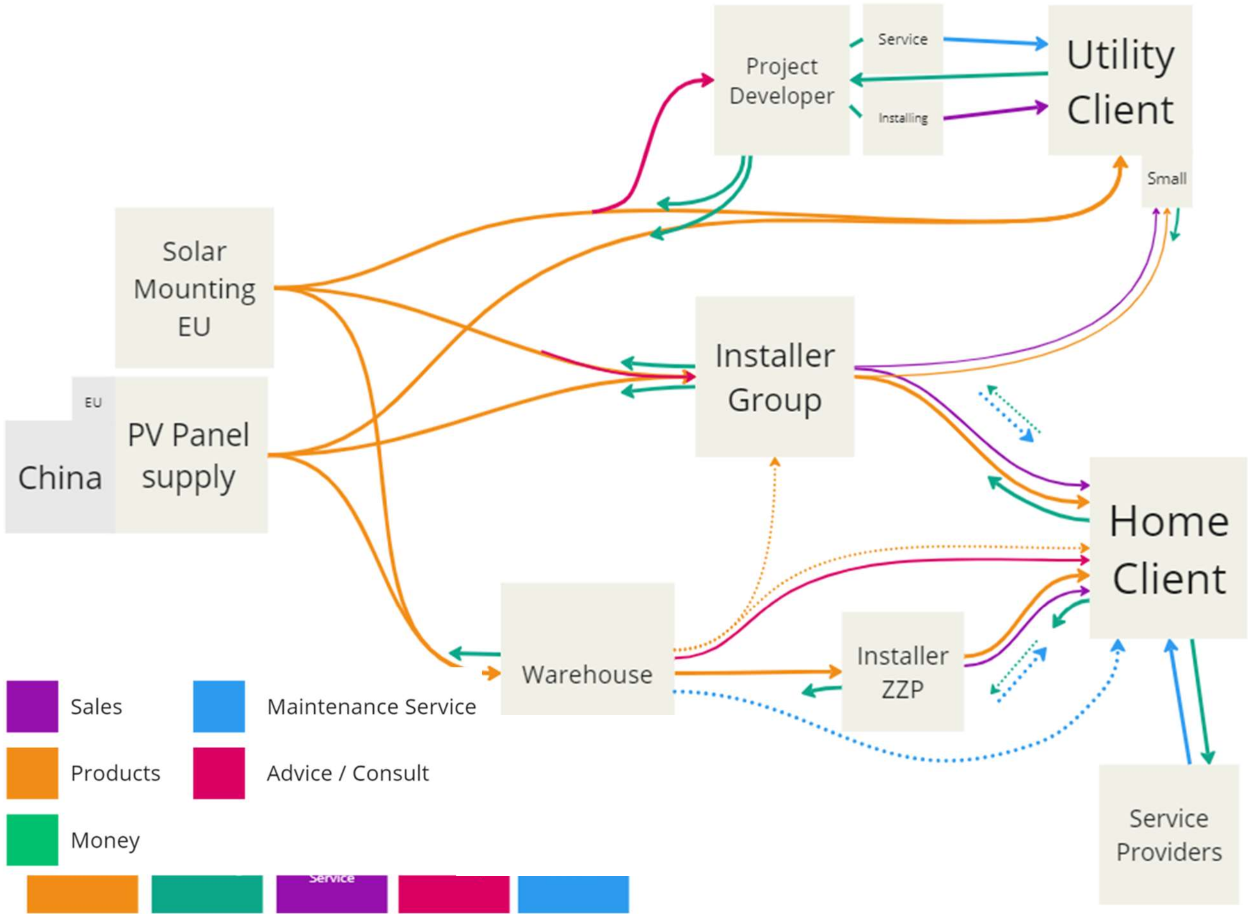


Figure 11: Overview of sales and value transactions in the solar installing industry, based on interviews (Appendix E)

3.4 Answering energy needs in grid and price

The fourth key driver determines how solar energy addresses customer needs for grid infrastructure and energy pricing (Appendix F). The industry could evolve towards collective infrastructure and centralised pricing or individualized self-sufficiency, affecting product stability and modularity requirements.

Collective Energy Infrastructure
While the costs of PV panels (modules) continue to decrease, overall system costs are stabilizing (RVO et al., 2023), because instalment and structure costs stay the same (MIT et al., 2015). Collective efforts in infrastructure planning could reduce engineering and installation costs (Balance of System, Figure 12), promoting the development of planned projects.

Individual Energy Sufficiency
High energy prices, measures against fossils and grid instability may push users towards self-sufficient solar solutions or energy conservation. With entry-level costs dropping (RVO et al., 2023) and the introduction of energy management systems and batteries, customers are increasingly choosing for independent solar setups. The higher costs in hardware and customer consult of residential sales (Figure 12), adds to the systems price and margins for stakeholders.

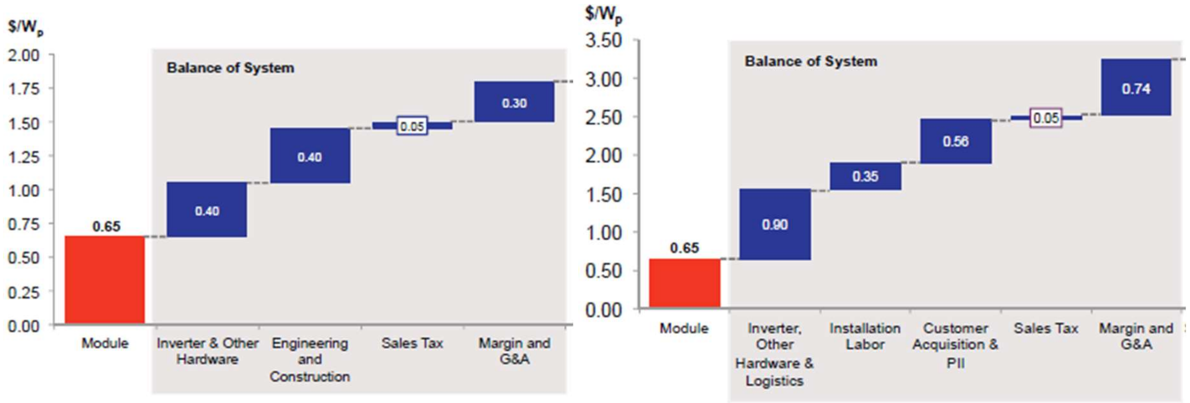


Figure 12 illustrates the cost distribution for utility (left) and residential (right) PV systems (MIT et al., 2015)

3.5 Geopolitical Energy and Product trading

The fifth key driver is the development of the international market and trade agreements, influencing the availability of materials and energy for production. This driver is interpreted from the Energy Security scenarios from Shell International Limited (2023). The industry may either benefit from free trading or face limitations/sanctions due to geopolitical tensions.

Free Trade agreements
Energy is a critical driver of wealth, determining the energy mix and shaping geopolitical stances on international cooperation. The European Solar ambitions (1.500 -> 93.000 TWh by 2050), underscore the need massive solar growth. To prevent massive energy shortages, the EU could strategically ensure a supply chain resilience by stimulating free markets (Shell International Limited, 2023), although potentially disregarding humanitarian violations in the supply chain.

Specific Trading Clubs
But energy dependencies also create geopolitical tensions. Alternatively, the EU might prioritize trade agreements with like-minded countries to secure energy supplies with strict carbon measures, limiting access to certain global markets (Shell International Limited, 2023).

3.6 Improved Sustainability of Production

The sixth key driver is the development of sustainable or circular production efforts (Appendix G). Whether driven by policies on energy and material resource-scarcity, or from environmental policies on supply chain emissions, the mounting industry must adapt to meet new standards.

Managing Scarce Resources
The EU may need to boost internal mining efforts to address resource scarcity of critical raw materials. From spilling over 90% of critical materials in 2024 (Rotmans, 2024), one measurement the EU is embedding obligations for recycling practices to close internal loops. Future policies could include energy conservations, strict carbon pricing, limits on international trading of certain materials/half-fabricates or helping local production and resources.

Circularity Systems and Chains
While construction materials are not scarce, local production facilities and human capital may become bottlenecks for solar mounting (MIT et al., 2015). Circular strategies like reuse or remanufacturing as well as international carbon trading could help to remain mass production and supply, just as minimising new product purchases.

3.7 Spatial Lay-out priorities

The seventh key driver is the development of spatial lay-out priorities (Appendix H). The ever going fight for space/area determines whether land and roof space are used primarily for energy needs or are shared with natural and social efforts.

Natural and Social efforts

Beyond rooftops, alternative locations (Appendix H) for solar installations offer potential, especially where structural limitations exist, as up to 26% of buildings (Systemic et al., 2021). Nationaal Dakenplan et al. (2023) describe four major functions of roofs: water management, social design, biodiversity and energy. Multifunctional solutions that balance energy production with water management, social design, and biodiversity are marketed and may become more common, though at the expense of maximum energy output.

Maximising Solar on Roofs

Most buildings (75%) can support solar installations with minimal interventions (Systemic et al., 2021). The connection of solar fields to the grid is a current limitation, advocating for energy production at the use locations, as utility roofs. And as spatial conflicts are stronger in land and natural areas, the Dutch government expresses a further preferred focus on solar installations on roofs (TKI Urban Energy, 2022).

3.8 The social acceptance and visibility sentiment for PV

The eighth key driver is the development of social acceptance and visibility of PV products. The available and marketed mounting-product options determine to which extent they are embraced by society, or are rather pushed back by social friction.

Social Friction

As explained in Appendix I, mounting solutions go from visible large fields on pitched roofs, up to seamlessly integrated PV in windows. BIPV and solar building elements (ETIP et al., 2021), while more expensive and less performing (Weeber, Appendix J), enable integration with existing structures. The luxurious products potentially boost acceptance of, now invisible, solar locations (De Jonge Baas, 2022). However, as energy needs and costs rise, social acceptance may become a issue of inequality, influencing norms and product regulations. According to Van Rijnsoever (2019), in a more polarised society, this public tension adds a strong dimension to the energy transition.

Proudly visible

Roofs and facades could provide for a tremendous amount of energy through solar installations (Appendix H). In the Netherlands, already 79% of solar power capacity is installed on roofs (Centraal Bureau voor de Statistiek, 2024a). And as solar panels on roofs is the most public accepted form of renewable energy (Rijksuniversiteit Groningen et al., 2021), this market could remain dominant. And by humanising the energy transition, for example through collective approach (key driver 3 and 4), it would create more support from society (Bloembergen, 2024).

As phase: **Future Backward Approach** | Determine End States

4. Industry Scenarios

Applying the future backward approach, I determined the area of potential development for each key driver, from the effects of Shell's scenarios. From these, I constructed a follow-up scenario and a sustainability-driven normative scenario (as explained in paragraph 1.3).

4.1 Sky 2050

The first Shell scenario is Sky 2050: a 1.5-degrees normative approach. It envisions a world where nations and industries work together to address climate change and transition to a low-carbon economy. With significant investments in renewable energy, technological innovation to reduce carbon emissions, and growing international collaboration to tackle environmental issues. Sky2050 highlights the importance of collective action, sustainable development and renewable energy sources for all. In Figure 13Figure 13, I will emphasize the scenarios potential on the key drivers and the positioning of both *Standardised Energy Capacity* and *Circular Energy.*

Standardised Energy Capacity: Mass out roll of solar panels on every roof, by optimising installing processes and accepting a minimal climate impact

The global energy production transitions towards renewables, strongly driven by the rapid out roll of solar energy. As citizens, businesses, and governments prioritise climate policies, the solar industry provides for the fastest energy transition and a low-carbon economy. It envisions a future where solar energy is an important focus in meeting the world's increasing energy needs, and boosts international industries. And while serving this 'greater good' of renewable energy security, it is step by step minimising the accompanied climate impacts through inclusion of innovation, sustainability, and collaboration in the international industry.

- Rapid growth of PV market driven by efficiency and standardization
- Integrated solar mounting services for efficient installations and adoption
- Certified installers ensure safety and quality standards
- Large-scale solar projects on roofs drive market consolidation
- Hydrogen and energy infrastructure expands to ensure reliability
- Low-carbon production industry grows competitively through policies

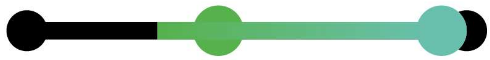
Circular Energy: Adoption of true circularity in Solar Energy solutions and the supply chain to achieve a fast ánd climate neutral energy system

In *Circular Energy*, the European solar industry puts itself as frontrunner of the transition towards circularity and climate neutrality, driven by its embedded purpose and environmental stewardship. This scenario envisions a future where the solar market embraces and reinforces sustainable PV production and distribution, creating a new era of climate-neutral energy solutions. All citizens and organisations of aspiring societies contribute to energy conservation, common ecological priorities and reuse- or shared product systems.

- Alternative PV technologies and sustainable production practices
- Climate-friendly policies and investments in low-carbon industries
- Reducing energy needs through insulation and consumption reduction
- Promotion of circularity throughout the entire integrated PV lifecycle
- Partnerships with PV producers to supply climate-neutral solar energy solutions

1. PV technology and products in market

Diversified PV products — Standardised PV panels



There is funding ‘to encourage both innovation and the more rapid adoption of existing solutions’ which could lead to mass panel usage. But ‘governments pour significant resources into technology development’, potentially creating several alternative PV types.

2. Production location of PV products

Sign. European production — Intern. production and supply

‘China’s experience as market leader in solar panel manufacture and electric vehicle technology is a template for Asia, Africa and Latin America’. The European PV production significance can only grow with large investments and lower demand.

3. Instalment projects and services

Collective Mass Instalment — Individual Diverse Sales

‘By working together such coalitions can quickly develop supply of a new energy technology, create the new markets that support that supply’ argues for the collective. But ‘competition drives a range to the top’, boosts innovation to sell the most low-carbon services to individuals.

4. Answering energy needs in grid and price

Collective Energy Infra — Individual Energy Sufficiency

‘Such coalitions can … provide enabling infra-structure’, and ‘public finances are prioritised for growth-enhancing green infrastructure investments’. But ‘Young people report their carbon use on social media, competing for the lowest scores’ as individual social response.

5. Geopolitical energy and product trading

Specific trading clubs — Free trade agreements

Embedded carbon transparency can also create ‘an emerging global order based on pragmatic agreements to reach common goals.’ But ‘Coalitions of trading partners come together to establish common standards for carbon measurement’ argues for joined ventures.

6. Improved Sustainability of Production

Managing Scarce Resources — Circular Systems and Chains

‘Looking beyond just transforming the energy supply’, states ‘Sky2050 requires deep circularity and CCS over the whole industry’. Besides these circular supply chains, supporting ‘domestic business puts these industries at the forefront of the global green industrial revolution’.

7. Spatial lay-out priorities

Natural and Societal efforts — Maximising solar on roofs

‘Innovative forms of citizen diplomacy spread ideas and encourage collaboration’ to potentially mass energy production. But an ‘bottom-up world order created around common priorities and objectives’ can also result into prioritising nature and life over energy and greed.

8. Social acceptance and visibility sentiment

Social Friction — Proudly Visible

‘Sharing fairly the economic, social and environmental benefits of the energy transition to all parts of society … is a precondition for making progress at pace in the energy transition…’ and would have to result in solar energy as a societal proud industry.

Figure 13: The development potential-range of the eight key drivers of Solar Energy, by the effects of the Sky 2050 scenario Blue = interpreted directions for Standardised Mass Energy. Green = interpreted directions for Circular Energy. All quotes retrieved from Shell International Limited (2023)

4.2 Archipelagos

The Archipelagos scenario envisions a world where energy security concerns dominate the global market. It focuses on self-sufficiency and independency, resulting in still quit fast but uneven progress in the energy transition. As the challenges for independency stimulate careful resource and energy usage, the world still moves towards net-zero emissions by the end of the century, with a global temperature rise peak at 2.2°C by 2100.
In Figure 14, I will emphasize the scenarios potential on the key drivers, and the positioning of both *Scramble for Energy* and *Power to People*.

Scramble for Energy: Heavy cost-pressing competition on an diverse market of Solar Energy products, to offer affordable energy self-sufficiency in an international scramble for energy.

This solar scenario envisions a chaotic and diversified international energy market, driven by price suppressing. In a world characterized by geopolitical isolationism, fragmented trade agreement and a scramble for energy resources, the solar industry tries to maintain an affordable and available energy source, still competing with fossils. Grid- and product-instability results into diversified market offers and energy inequality, leading to social friction. Individuals are left to their own efforts for energy sufficiency by instalment and use of solar products, while governments protect domestic industries.

- Panels flood in from global suppliers, notably China, offering varying quality
- Product and service providers mitigate for grid instability
- Solar industry adapts offerings to diverse needs, empowering consumers
- Companies and AI navigate diverse clientele in a complex market
- Industries prioritize cost and reliability, driving domestic production

Power to People: Socially repurposing and allocating available Solar Energy, whilst improving domestic wealth and climate adaptation

In the geopolitical landscape of the Archipelagos scenario, marked by an international scramble for energy resources, the society adapts its activities in solar to contract and distribute the available solar energy so to balance industry and citizen needs. As society observes a growing global isolationism, it now shifts towards a domestic focus for wealth preservation and climate adaptation, strengthening collaborative actions with like-minded pv producing countries. Solar energy is now brought to all citizens within a community in collective local actions balancing society, nature and wealth.

- European PV supply relies on joint contracted imports, varying in quality.
- Solar focuses on domestic wealth and fairly distribution industry and users.
- Contracted PV supply is tactically distributed in regionally for energy stability.
- Community-based solar initiatives drive social equality and climate adaptiveness.
- Industries prioritize domestic production and circular economy principles.

1. PV technology and products in market

Diversified PV products — Standardised PV panels

'Selling the same-sourced goods to different country groupings under different rules, forms a new key business opportunity' argues for chaotic markets. But also sets up 'transactional agreements, for technology sharing, industry partnerships and the guaranteed supply of goods'

2. Production location of PV products

Sign. European production — Intern. production and supply

'By 2040 a multipolar trading world has developed with fierce competition for trade with India and some African and Latin American nations.' And although domestic industries are protected, all supply that wasn't there can't barely be created.

3. Instalment projects and services

Collective Mass Instalment — Individual Diverse Sales

'Groups of nations now scramble to secure energy supplies and focus on building energy resilience to withstand future shocks.' This can either be individual or collective, as 'autocratic regimes seem to offer clear solutions, even if those solutions limit individual freedoms.'

4. Answering energy needs in grid and price

Collective Energy Infra — Individual Energy Sufficiency

'Fossils compete with broadening range of applications for, and deeper use of, battery-based energy storage...' and 'flexible demand' possibly at home. But also 'battery storage at a massive scales' rises as are 'optimistic futures for technology rising to this challenge'.

5. Geopolitical energy and product trading

Specific trading clubs — Free trade agreements

'A multipolar trading world has developed with fierce competition for trade with India and some African and Latin American nations', but 'many emerging economies enter into transactional agreements, for industry partnerships.... supply of goods and services'.

6. Improved Sustainability of Production

Managing Scarce Resources — Circular Systems and Chains

'In an effort to protect domestic industries, some countries come together to form carbon clubs ... and then implement carbon border adjustment mechanisms.' But 'these groups drive pockets of climate action, but a vicious cycle of protectionism plays out. Showing it can be both.

7. Spatial lay-out priorities

Natural and Societal efforts — Maximising solar on roofs

Because of oil and energy prices, 'In the Archipelagos scenario, this [solar energy] grows to around 400 TWh by the early 2030s. 'But climate change may mean that society has to shift towards a state of continual adaptation, particularly for agriculture.'

8. Social acceptance and visibility sentiment

Social Friction — Proudly Visible

'More empowered and vocal younger voters seek justice, accountability and the redress of systemic inequalities that they argue have been caused by capitalism.' But 'autocratic regimes seem to offer clear solutions, even if those solutions limit individual freedoms.'

Figure 14: The development potential-range of the eight key drivers of Solar Energy, by the effects of the Archipelagos scenario.. Purple = interpreted directions for Scramble for Energy. Orange = interpreted directions for Power to People. All quotes retrieved from Shell International Limited (2023)

5. Scenario Construction

For each industry scenario described in chapter 4, I created a product scenario. Each scenario is translated to a designed product system, differentiating in type of PV product, mounting services, solar energy clients, sustainable effort and spatial arrangement (Table 3). The substantiation for the construction of these product-system contexts is found in Appendix L. Each product scenario is further explained through the fulfillment of the minimal requirements (Table 4), the sustainable efforts (Figure 15) and the visualised spatial arrangement (Figure 16). For each product-system outline, I eventually developed a resembling conceptual product-design, service-design and business design (Chapter 6-9).

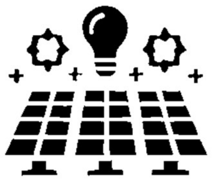
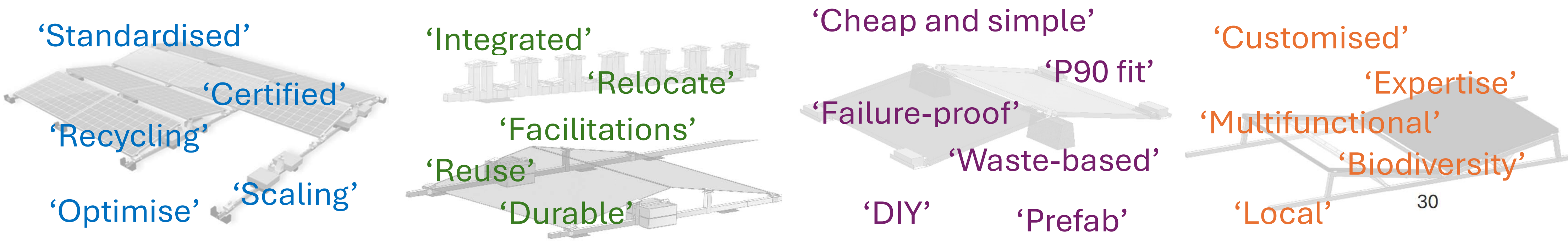
Scenario	 PV products (Table 4)	 Mounting (Table 4)	 Clients	 Sustainability (Figure 15)	 Spatial arrangement (Figure 16)
Standardised Mass Energy	Uniform, high-efficiency, large-scale panels	Rapid deployment, standardized, robust systems	Governments, large corporations; bulk purchases	Low-carbon materials, optimized production processes	Extensive solar fields, mass rooftops, centralized infrastructure
Circular Energy	European production, Durable, modular, recyclable	Modular, easy to disassemble and repurpose	Environmentally conscious businesses; lifecycle-focused purchases	Recycled materials, reuse focus, circular economy principles	Minimal use of roofs, local and grid supply, energy conservation
Scramble for Energy	Varied quality, all sizes, mix of high-performance and low-cost panels	Flexible and chaotic, adaptable to various environments, DIY-friendly	Diverse clientele; price-driven, immediate availability purchases	Minimal focus on sustainability, driven by cost and necessity	Chaotic, diverse locations, infrastructure struggles
Power to People	As import batches, different production originations	Customisable to tenders, locally-supporting products & installations	Local communities, cooperatives; socially motivated purchases, governmental tenders	Local sourcing, minimal impact, easy maintenance	Multifunctional spaces, decentralised, integration with greenery and community spaces

Table 3: Product Scenarios overview

Table 4: Fulfilling of Program of Requirements per scenario (see Appendix A)

Installation			
Standardised procedure	De-/re-installation facilitated	Failure-proof ease	Customised Ease
Optimisation of supply chain	*Supply chain integration for reuse*	*Installation by cheap labour and DIY*	*Installation by local group*
Structure (weight)			
<<15 kg / m2 + ballast	≥ 20kg/m + minimal ballast	18-20 kg/m2 + standard ballast	18 - ≥20kg/m2 + ballast
Ffor all roofs	*Quality over quantity, not all roofs*	*Standard weight, P90 product fit*	*Quality over quantity, not all roofs*
Project Performance			
Preassembled Fast & Mass	Modular Reuse System	Prefabricated Fast Options	Multifunctional custom
Minimised install actions	*Remain, remanuf., replace, relocate*	*Fast DIY or Energy as a Service*	*Expert Bio/Nature matching*
Mounting (of PV product)			
Standard sized panel (50 mm clamp)	Frameless PV panel (distributed surface)	Weak panel of all sizes (>>50 mm clamp)	Batch and contract depended
Materials			
Low-carbon / green recycled steel	Low-carbon / green recycled steel	Waste-based, local or temporary stock	Waste-based, local recycled (steel)
Providing mass low-carb production	*Minimising all impacts*	*Minimise dependency*	*Boosting local industry*
Secure (Ballast)			
Carbon Capture Storage concrete	Water, grint, waste	Waste or Waste-based product	Water, greenery/wood CCS concrete
End of Life			
Closed-loop recycling	Modular reuse	Second hand / temporarily reuse	Extend life with add-ons
Safety			
In certified personnel	Over dimensioned product use	AR/AI quality check	Certified quality checker



Figures from Chapter 6-9

As the ambitioned 'climate neutral product' does not reflect all circular or sustainable aspects of the system, I also contextualised the scenarios on the prior sustainable design objective (paragraph 2.2): evaluating the sustainable handling of PV and mounting products. I looked at the sustainable strategies in *circular product design for the technocycle* (remain, reuse, remanufacture, recycle, reduce), *production resources* (waste based, local production, energy efficiency) and added climate adaptation. Substantiations for these sustainability ratings are to be found in Appendix N.

It shows how both the Circular Energy and Power to People scenario are strong normative sustainable alternatives for their counterparts.

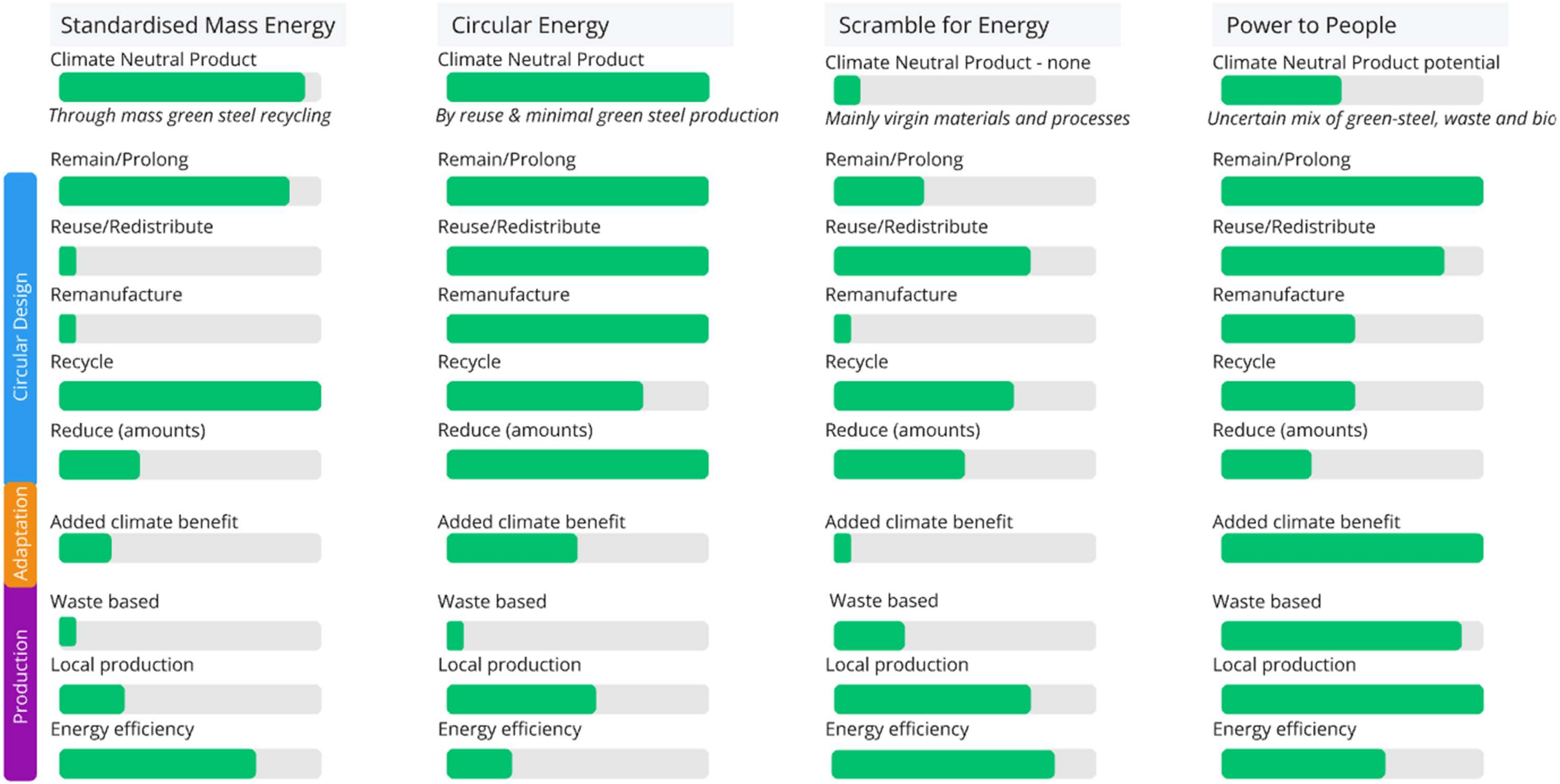


Figure 15: Sustainable efforts per scenario

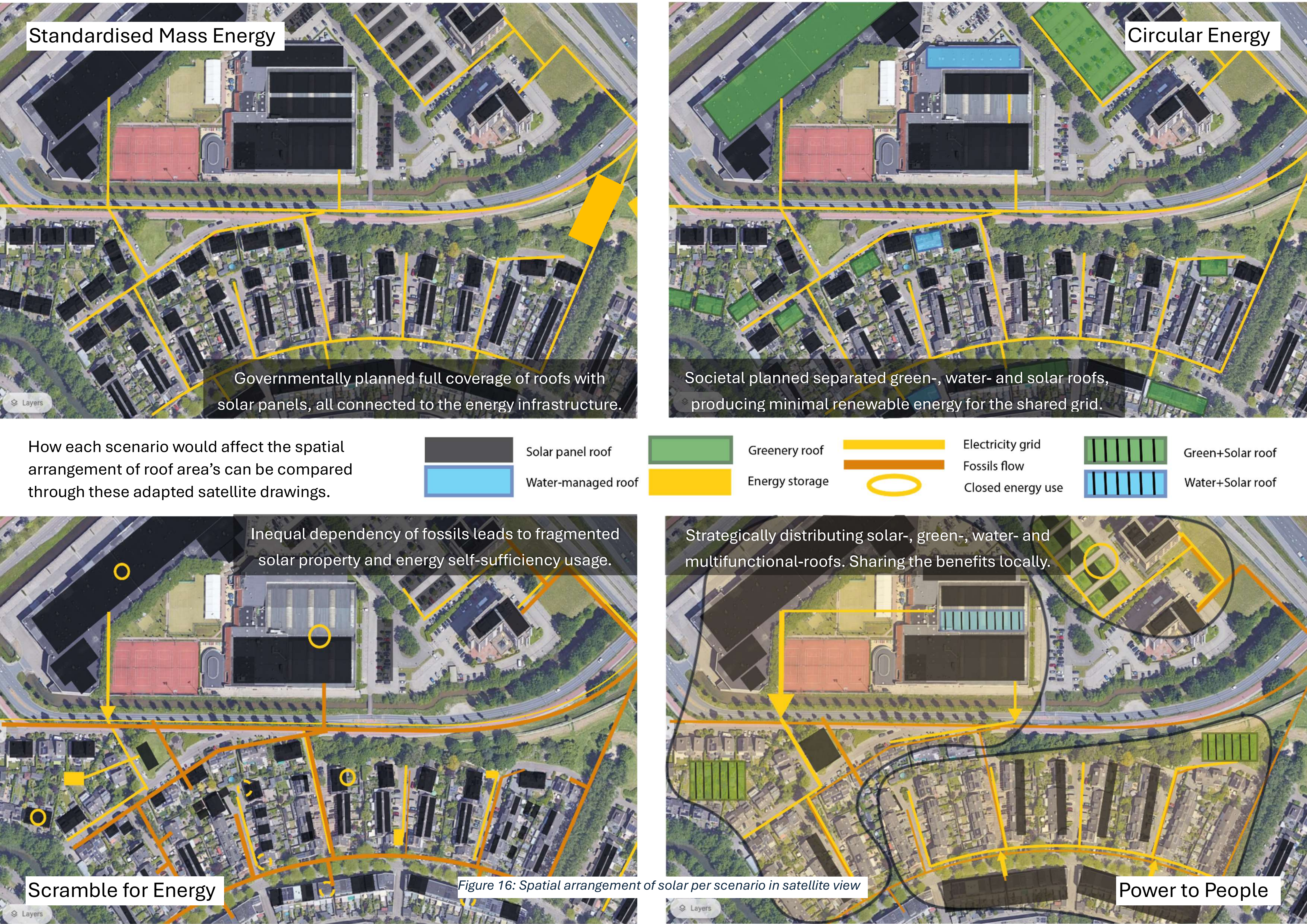


Figure 16: Spatial arrangement of solar per scenario in satellite view

H6 Standardised Mass Energy

Mass out roll of solar panels on every roof, by optimising installing processes and accepting a minimal climate impact

Figure 22: Visuale of Standardised Mass Energy scenario, created with DeepAI

Summary:
Standardised Mass Energy envisions a future where solar energy systems are mass-produced and heavily standardized to meet global energy demands efficiently. PV products in this scenario are uniform, with a focus on large-scale, high-efficiency panels that can be easily deployed across vast areas. Governments and large corporation require mass solar project developers that prioritize speed and efficiency, enabling fast installation on every available rooftop. These project developers will invest to become mass employers of installers, purchasing and installing fully standardised solar mounting systems. Sustainability efforts are primarily focused on optimizing production processes (with low-carbon steel) to reduce carbon emissions, and creating mass recycling streams. The spatial arrangement in this scenario is dominated by extensive solar fields and rooftops, with infrastructure designed to support centralized energy production and distribution.

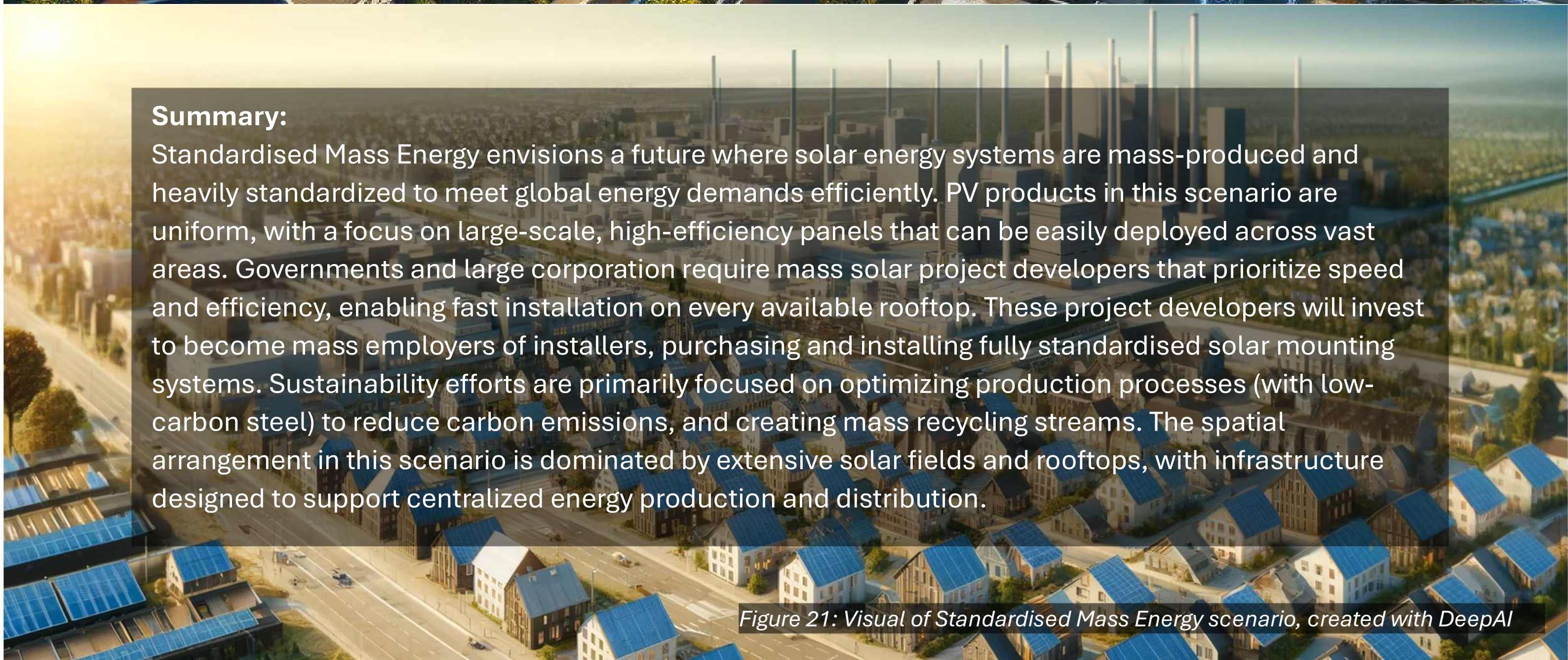


Figure 21: Visual of Standardised Mass Energy scenario, created with DeepAI

6. Standardised Mass Energy

6.1 Scenario Drivers

The schematic below shows how the eight key drivers of solar energy would develop into this scenario.

1. PV technology and products in market

Diversified PV products — Standardised PV panels

The performance of PV keeps developing within the mass produceable technologies. As supply and installation happens on massive scales, the PV is produced within standardised panel dimensions for logistic handling.

2. Production location of PV products

Sign. European production — Intern. production and supply

Massive cheap-labour production has been growing in China. The economical interest triples down to further Asia, Africa and Latin America. By mass market demand from Europe a standardised size, quality and performance maintains.

3. Instalment projects and services

Collective Mass Instalment — Individual Diverse Sales

For a mass solar capacity installation, projects are only organised on large-scale collective basis. Consolidation in the market drives standardisation and minimal prices. Human capital shortage drives prefabrication and automation.

4. Answering energy needs in grid and price

Collective Energy Infra — Individual Energy Sufficiency

As residential roofs can provide more than the energy households need, all energy flows through the grid to be stored and shared efficiently amongst society and industry. Available electricity supply drives infrastructure development.

5. Geopolitical energy and product trading

Specific trading clubs — Free trade agreements

A focus on electrification makes society and industry growingly independent from fossils. Through stimulating international markets for PV production, dependency for solar panel supply is spread.

6. Improved Sustainability of Production

Managing Scarce Resources — Circular Systems and Chains

The industry transforms the supply chain, rather than the product. With a growth of renewable energy and grey, blue and later green hydrogen, circularity through efficient recycling and reproduction creates near-climate-neutral business.

7. Spatial lay-out priorities

Natural and Societal efforts — Maximising solar on roofs

As full roof surfaces and land installed projects can provide all needed solar, the efficiency focus is on large installing programs for such locations. Other applications are unnecessary complex.

8. Social acceptance and visibility sentiment

Social Friction — Proudly Visible

Apart from some simple installed BIPV in new buildings, roofs and fields are sufficient for energy production. So solar panels reach an accepted and beneficial sentiment.

6.2 Product and Service

Product requirements

Product development focuses on the '1-ProductSystem fits all' service. The solar mounting industry unifies and standardises install practices, to serve all types of roofs and buildings under a simple general method of execution. Systems become mass compatible and installation is standardised and potentially robotised or prefabricated.

This standardisation does not come from the government per se, but more from the producers and the consolidating amongst project developers that install. Another important aspect is strict insurance and warranty by certifying of installations and installers. Therefore, the mounting products together with its installers method undergo strict norms, standards and safety tests.

Approaching solar mounting from mass scalable low-carbon design perspectives, the product requirements will be added and modified to:

Table 5: Abbreviated list of requirements for SME product, full list Appendix A

Requirement	Value/ Aspect	Purpose
Installation	Standard procedure	Optimisation of supply chain by similarity
Weight of structure	<<15 kg/m2	Topology based minimising of materials
Mounting	Fit for all roofs	Consolidation to one system + one panel = efficient
End-of-Life	Mono materials	Fit for mass efficient closed-loop recycling industry
Material Production	Low-carbon / green / recycled steel	Minimising climate impact, while providing mass production
Project	Prefabrication	Minimised install actions and joining materials

Product

For this scenario, I did not design a new product. The existent product mix of certain market leaders is in line with this scenario's product development, driven by optimisation and mass compatibility. Two examples are Van der Valk systems and Sunbeam.

Figure 23: A solar mounting system by Van der Valk, exemplary for the SME scenario (Van der Valk, n.d.)

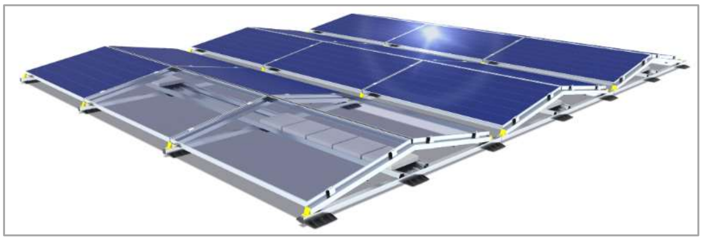


Figure 24: A solar mounting system by Sunbeam, exemplary for the SME scenario (Sunbeam, n.d.)

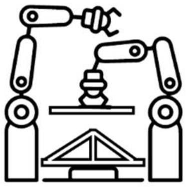
Through the years, both products are developed into mass efficient standardised install products. Adjustable in lengths, minimising in steel material usage and suited for proper ballast calculation for application on almost any roof. The product designs should be able to evolve into an industry standard steel-type, producing from a mono material that is low-carbon and eventually green steel. Further prefabrication and some automation with these structures could be possible, if cost beneficial from a mass installation perspective.

Services and supply chain

All producers and installers of solar mounting solutions work on the same basis of execution throughout the lifecycle, as it is the most efficiency-optimised outcome:

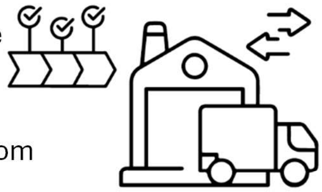
In the ***Production*** phase, all products are produced from separatable and, within material type, mono materials. This results in a mix of green steel, green aluminium, recycled plastics and others. The production industry is spread out globally, wherever low-carbon materials and production are the cheapest.

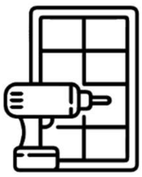
By ***Preassembling*** and ***Prefabrication*** of solar mounting elements, the producer together with project developers create fast and pre-certified partial installations for roofs.



For ***Project Consultation*** there will be specialised mass-scaled project engineers with the knowledge on install efficiency and minimal adapting practices. Their goal is to reduce building's structural complications, creating zero risks and minimal spatial loss in mass solar project plans.

The ***Carbon and sustainable transparency*** needs to be very specific to be allowed within sales tenders. All ***Transport*** practices will have to comply with the transports sectors sustainability goals. As transport is optimally integrated in the supply chain, trucks driving on renewable energy are custom rebuilds for fast unloading and lifting of partial mounting installations.





For ***Installation*** practices, a project developer will train expertise teams on standard procedures in construction and mounting situations, working with a specific product portfolio and providing safe working conditions. Installation itself will be guided by more robotised tasks in lifting and heavy load placing.

Afterwards, ***Service and Maintenance*** is specialised by external parties, who are involved on the subject of insurance and warranty, as rightful replacement and cost coverage is important to support business cases.

For the ***End-of-life***, reuse and remounting in other projects is neglected for its unnecessary complications and costs.
Therefore, the strategy is on ***recycling***. All mounting systems can easily be disassembled and are take into a high quality recycling system of (international) industry producers. For the PV itself, the government has set up a unified recycling facility for separated recycling of all critical materials.

6.3 Sales and Value Chains

In the *Standardised Mass Energy* scenario, the installation market is driven by efficiency and scaling. The sales market is focused on winning large commercial and public solar projects for energy production with gradually increasing sustainable demands. The mass demand for solar energy has pushed out small scale residential projects, and steered on collective mass requests. As a result of an extreme cost pressive environment, market consolidation (JBR et al., 2024) has occurred. The value chains of the new sales process are illustrated in Figure 25.

As depicted in the big circle, there are only a few major project developers left, working with licensed installer-personnel, trained and experienced in a specific solar mounting brand, stocked in-house. That means that project developer X has conformed itself for a certain time frame to mounting system X, and is certified to install qualitative and safe mega projects.

<u>Supply</u>
All project developers compete on cost-price of the entire PV-products through contracting suppliers around the world (from scaling mostly Asia). To their suppliers of mounting systems, a more European and influenceable market, they keep constantly pushing for minimal supply costs and optimal sustainable numbers.

<u>Clients</u>
These major project developers compete on winning over mass utility projects, including big corporates and collective industry area's. There other clients are collective residential projects, being controlled, obligated and organised by local governments. The eventual transaction can be organised as a mandatory or stimulated client participation in collective ownership, or a public financed project.

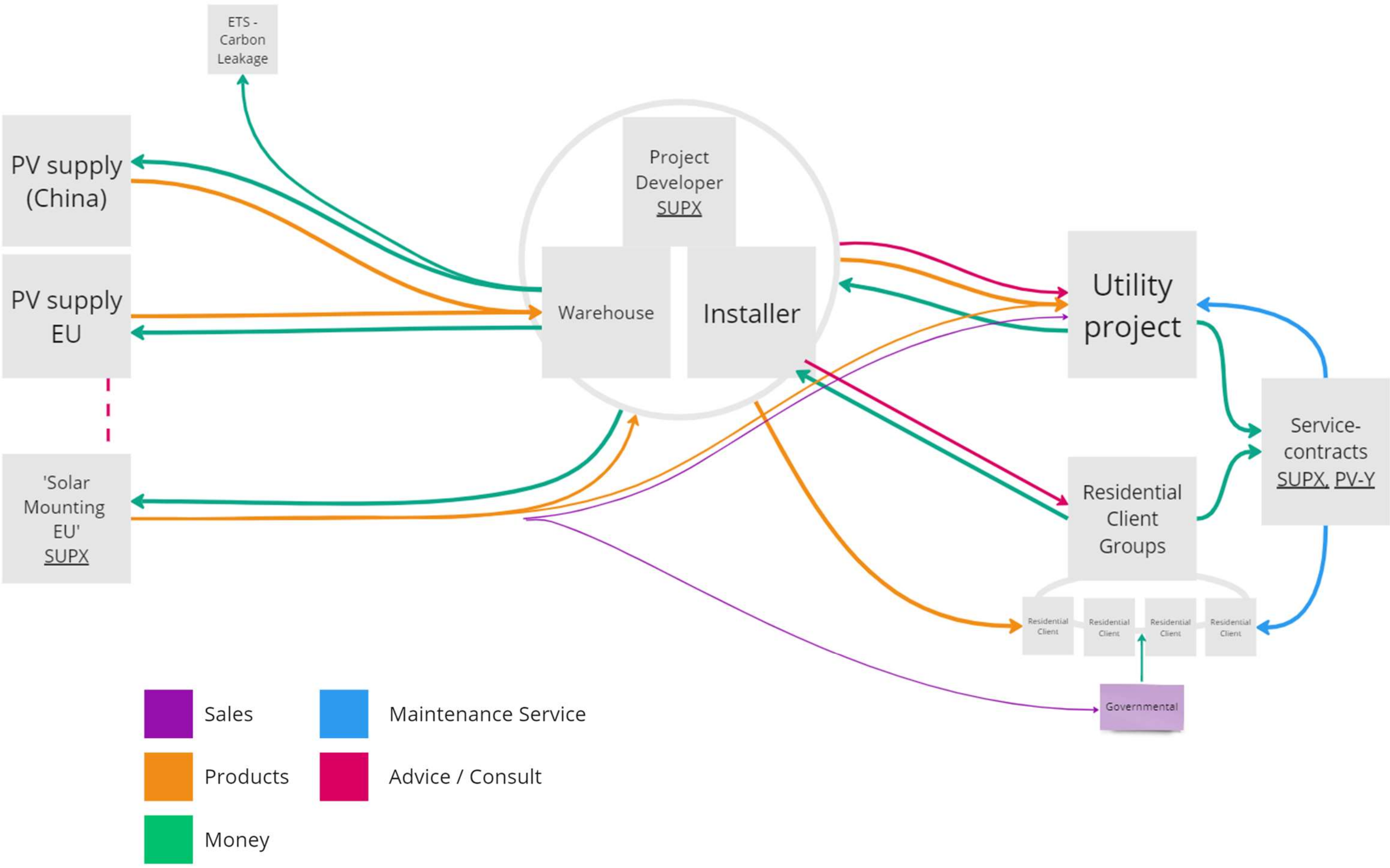


Figure 25: Schematic of the new value chain in the SME scenario. Consolidated Mounting Suppliers advertise their products as qualitative best to utility users and governments. Contracted project developers install with one preferred mounting system, and have included warehousing and installer employment to grow their efficiency.

H7 Circular Energy

Adoption of true circularity in Solar Energy solutions and supply chains to achieve a fast and climate neutral energy system

Figure 27: Visual of Circular Energy scenario, created with Dall-E

Summary:
Circular Energy prioritizes a sustainable and resource-efficient approach, where European PV products are designed for longevity, recyclability, and (near-)zero environmental impact. Solar mounting services provide modular reuse-systems that are easy to disassemble and repurpose, reflecting the circular economy principles. Customers, including environmentally conscious businesses and municipalities, will invest in facilities for reusable solar panels and mounting systems, focusing on long-term durability over initial costs. Service providers or individual customers will maintain, upgrade, relocate and eventually recycle their solar mounting products. Spatially, this scenario promotes planned segmentation of spaces, where solar roofs coexist with green roofs, urban gardens, and other ecological initiatives. This societal integrated solar energy is locally distributed and sold, also applying to individual energy responsibilities to stimulate energy conservation efforts.

Figure 26: Visual of Circular Energy scenario, created with Dall-E

7. 1 Scenario Drivers

The schematic below shows how the eight key drivers of solar energy would develop into this scenario.

1. PV technology and products in market

Diversified PV products — Standardised PV panels

Market and government regulations demands PFAS- and Lead-free PV. New alternative production enables sustainable, frameless and recyclable panels or other forms.

2. Production location of PV products

Sign. European production — Intern. production and supply

Investments in European production are necessary to start circular frontrunners. This creates a mix of supply origination, but sets up certain climate neutral standards, applicable for European recycling and reuse.

3. Instalment projects and services

Collective Mass Instalment — Individual Diverse Sales

A purely circular system for solar demands an integrated and controlled supply chain. Mass circular reuse, repair and recycling of individual owned products needs a collaborative approach for installing, facilities and service.

4. Answering energy needs in grid and price

Collective Energy Infra — Individual Energy Sufficiency

Minimal energy usage and durable handling of products works best at an individual responsibility. With organised means, housings (-corporations) and companies are individually responsible for their energy production and reduction.

5. Geopolitical energy and product trading

Specific trading clubs — Free trade agreements

The international market is not sufficient for the climate goals of the EU. Strategic collaborations and policies will lead to exclusion of markets. EU invests in mining and urban recycling of critical materials. Carbon pricing is strong.

6. Improved Sustainability of Production

Managing Scarce Resources — Circular Systems and Chains

By strong carbon pricing and carbon leakage policies grows a domestic fully circular supply chain. As the only pure circular strategy is constructing a complete reuse, repair, remanufacture and recycle system.

7. Spatial lay-out priorities

Natural and Societal efforts — Maximising solar on roofs

The spatial arrangement of solar energy is strictly judged, only supporting projects that do not lead to deforestation or biodiversity loss. Investment in technology of high efficient panels and energy conservation limits spatial need.

8. Social acceptance and visibility sentiment

Social Friction — Proudly Visible

As a pure circular energy will be initiated bottom up, by society, showing a climate neutral form of renewable energy is proudful. Sustainability is hot, and it shows.

7.2 Product and Service

Product requirements

As climate neutrality of the (solar) industry in 2050 is the national priority, many circular reuse initiatives have led the development and application of reusable solar mounting systems. But as many products only come free for reuse after many years on the roof, many different products enter the reuse market. These are gradually replaced by size-compatible reuse systems, based within a greater steel frame reuse program.
Approaching solar mounting from pure circular design perspectives, the product requirements will be added and modified to:

Table 6: Abbreviated list of requirements for CE product, full list Appendix A

Requirement	Value/ Aspect	Purpose
Installation	De-/Reinstallation	Supply chain integration for reuse process
Weight of structure	≥ 20kg/m2	Quality of product is priority. Not all roofs enabled.
Mounting	Frameless option	Mounting of frameless PV products / thinfilm
End-of-Life	Modular reuse	Disassemble, repair, remanufacture optimised
Material Production	Recycled / green / low-carbon steel	Minimising climate impact, while using local waste steel
Ballast material	Water, grint, waste	Using materials that are already in circular use

Product

For this scenario, I designed a solid reusable and scalable solar mounting system.

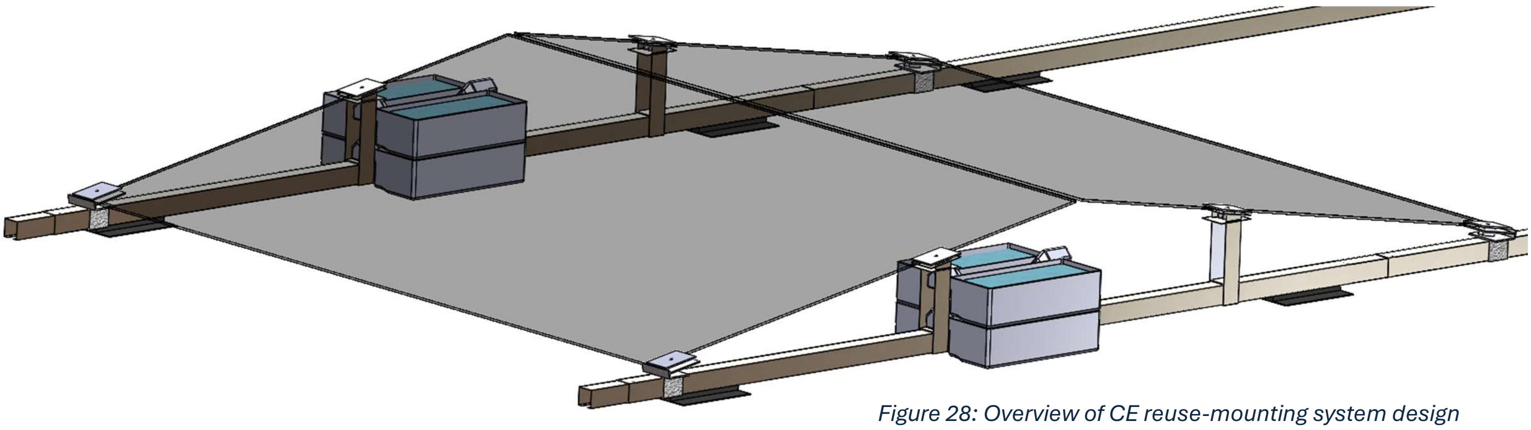


Figure 28: Overview of CE reuse-mounting system design

In larger field configurations, the systems works quit the same as the existing solar mounting fields for utility. As seen in Figure 30, all bas-units are interconnected in the lengthening direction. Only if necessary for the calculated ballast, an extra install effort can be made, also cross connecting with another set of the same base-units.

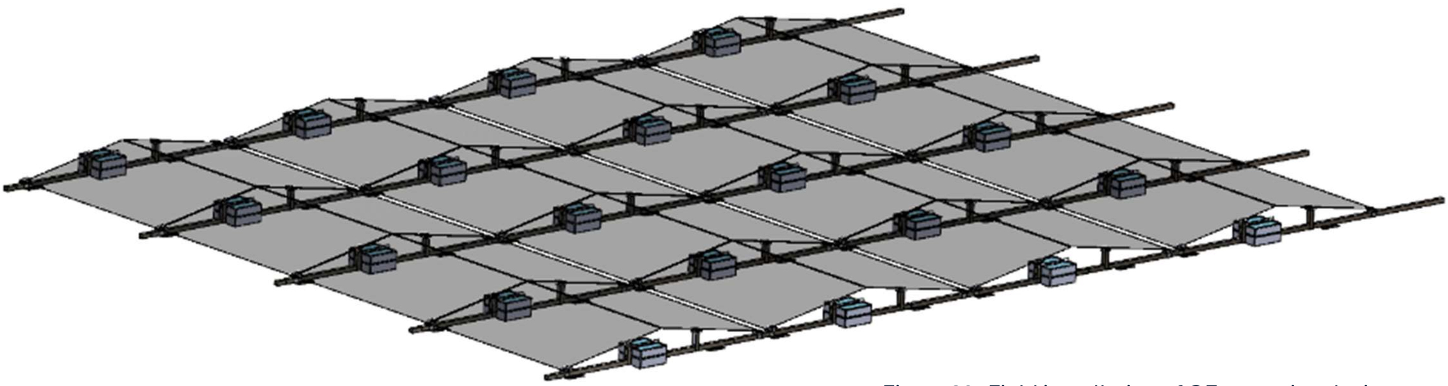
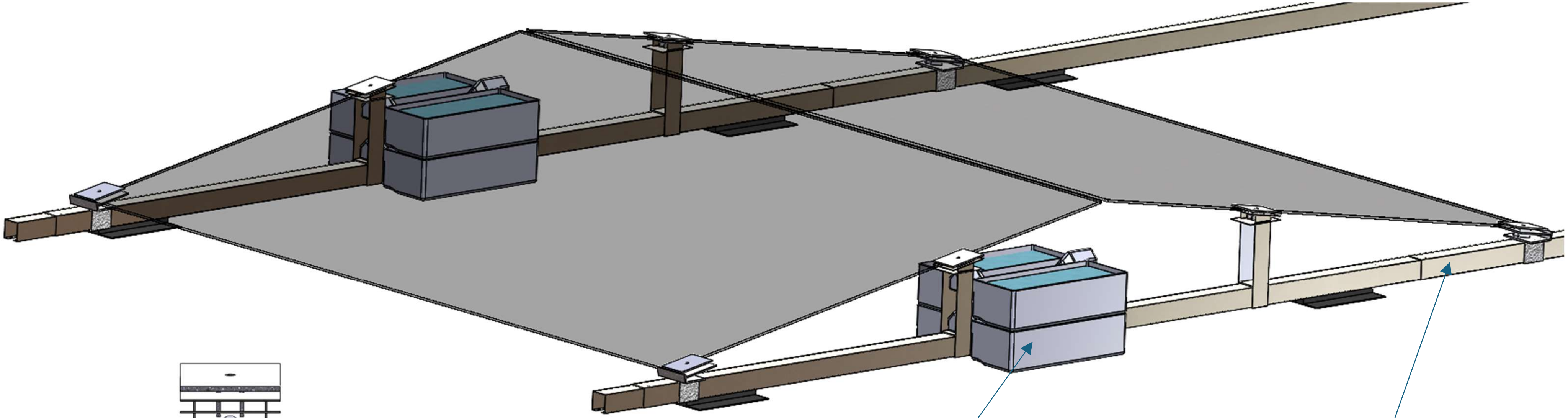


Figure 29: Field installation of CE mounting design



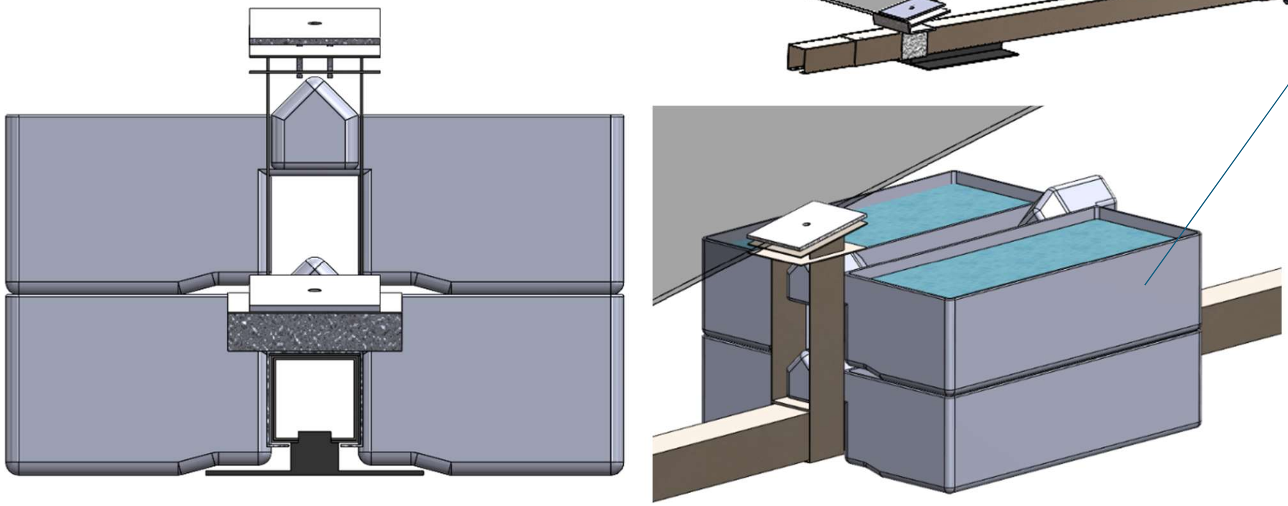


Figure 31: Reusable, water filled ballast system.

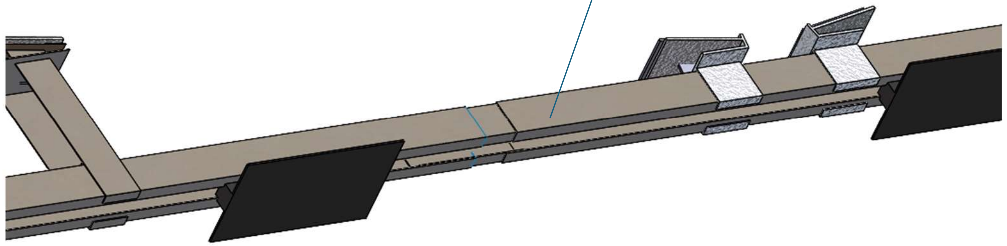


Figure 30: Interconnectable one-size base units supporting reuse

This mounting systems applies reusable containers to create ballast. They can be filled with water, gravel, or other widely available reusable / renewable materials.

As shown in the side view, the containers can be stacked seamlessly around the base unit and over the foot. It is a thick injection moulded product from recycled plastic.

For the base unit, this system uses standard steel profiles from the larger logistics industry. It enables for an independent installation of one-length base units, reusable across any roof configuration.

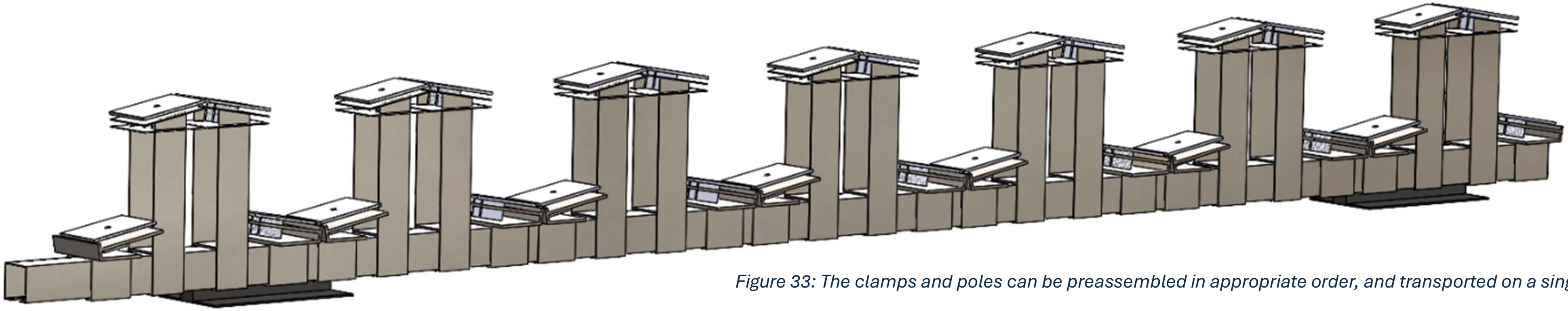


Figure 33: The clamps and poles can be preassembled in appropriate order, and transported on a single beam

The clamps and carriers are integrated, and can be slid over the base units up to the proper distance for the applied panels and configuration (figure below). In transport and project-planning, they can be prefabricated on the first base-unit in the proper preassembled order for configurations (east-west or south). All remaining base-units are stacked separately and can be installed on the roof at once, before the panels.

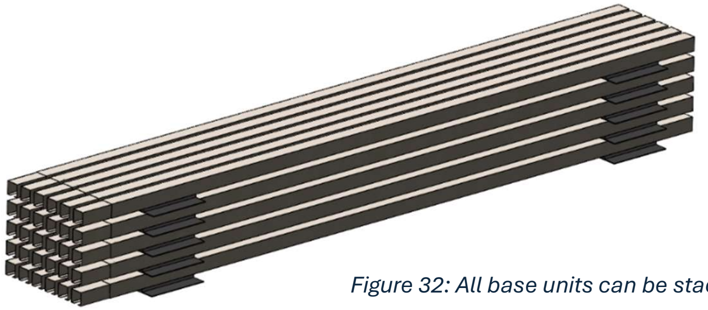
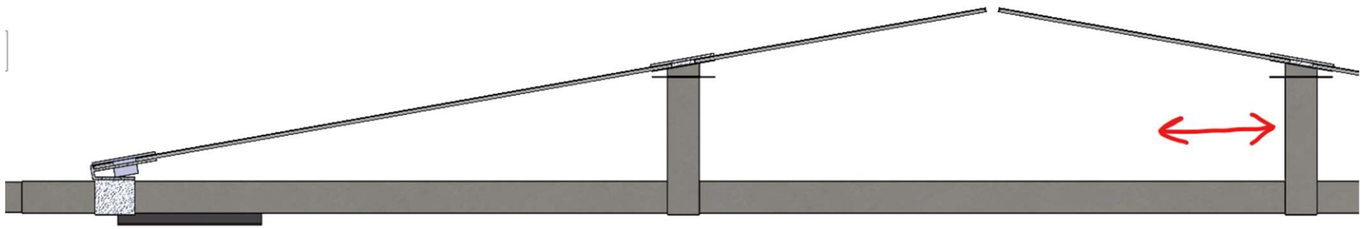


Figure 32: All base units can be stacked efficiently



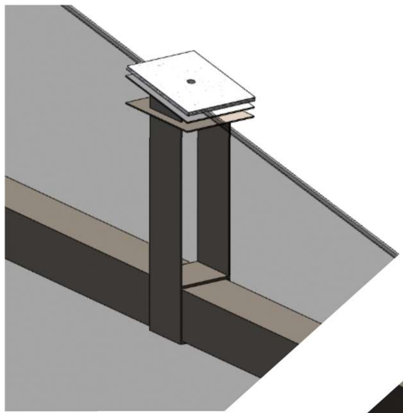
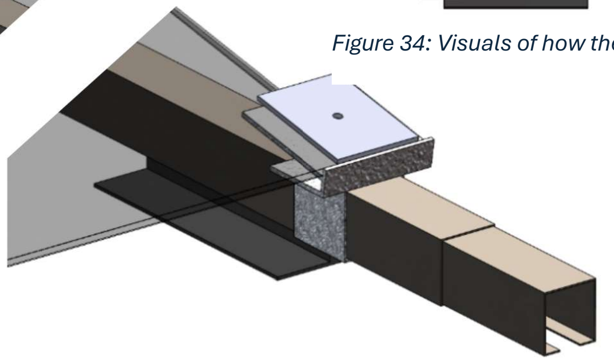


Figure 34: Visuals of how the clamps and poles slid over a beam, and fit any panel length



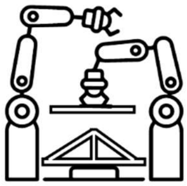
The panel clamp is enlarged for the potential use of frameless PV panels. Installed under a fixed angle of 10°, the higher pole-clamp is to slid backwards up to touching the panel. Then, the remaining length of the panel can simple lean over as far as it needs. This system is also possible with framed PV panels.

Services and supply chain

An reuse system for solar mounting impacts all phased of the supply chain. From slowly renewing production to strong maintenance and control practices:

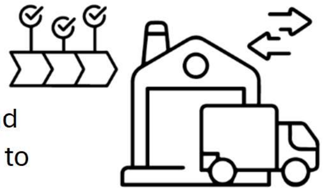
In the ***Production*** phase, all products are produced from qualitative materials. As circular reuse system only grows to large scale after the 20-25 years of first - time product use, the most products are originally produced before a green steel realisable time frame. Therefore, the products are made from gradually increasing percentages of low-carbon and recycled steel.

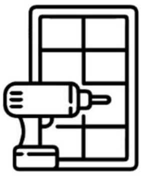
By ***Preassembling*** the clamps in correct order on the first-in-row base-units, the product is prepared for the correct configuration. Together with the separately installable base-unit fields, this provides for a fast and mass reusable take-back and reassemble system.



For ***Project Consultation*** there will be calculating project engineers that match supply and demand of the reusable parts, whilst planning on install efficiency and minimal adapting practices. Their goal is to collectively target a certain area, district or location to efficiently realise solar energy on all simply suited roofs.

The ***Transport and Logistics*** are of significant size in a reuse system. Luckily, a reuse-system for solar energy products, with a 20-25 lifetime, is more manageable. The product handling is optimised for product safety and transparent product-tracking. The logistical infrastructure is set-up locally, to serve small-distance climate neutral traffic.





For ***Installation*** practices, a project developer will train expertise teams on standard procedures in construction and mounting situations, working with an almost fully standardised product portfolio. With single base-unit, foots and ballast products, and just the minor adjustable/unique pool of clamps/poles.

Afterwards, a ***Remain, Repair and Retrieve*** department of the organisation is involved in regular safety and performance checks. They deliver the necessary maintenance and repair services and include a deinstall and take-back service for broken or planned relocated panels and mounting structures.

For the ***End-of-life***, the retrieved products are taken back to a facility where they are performance-evaluated, recertified, repaired or refurbished. Then they are stored and listed for new project planning by project engineers.
When products are definitely non usable, the last strategy is ***recycling***. All mounting systems are taken into a high quality recycling system. For PV, there is a unified recycling facility for separated recycling of all critical materials.

7.3 Sales and Value Chains

To enable a fast energy transition, solar installation will be installed over entire districts in public and private projects. As these large projects demand for strong executive organisations, market consolidation has led to the integration of warehousing, installing and project developing.
In *Circular Energy*, the strong priorities for climate neutrality drove the offered services through proving and advertising collective climate neutral or carbon negative solar systems to private and public finance tenders.

Supply
For efficiency and quality, project developers dedicated the start of their business to one (or two) panel and mounting suppliers, with a standardised set of trusted low-carbon new products.
At the same time, by contracting project developers, a few key players in the mounting industry have gained the exclusive suppliers rights. Consolidation of the market has led to only a few key players in mounting-systems, collaborating on minimal add-on products for European PV suppliers.

Client
In consultation, the project developers have integrated warehouses and installers into their service, navigating mass reuse of the solar-mounting brand(s) of their contracts.
At last, there are departments, as well as stand-alone service contract providers that are specialised in a specific older/foreign mounting product or PV type for maintenance and repair, as this includes more specialised knowledge. When a product take back is necessary, they transport to the redistributing facilities of project developers.

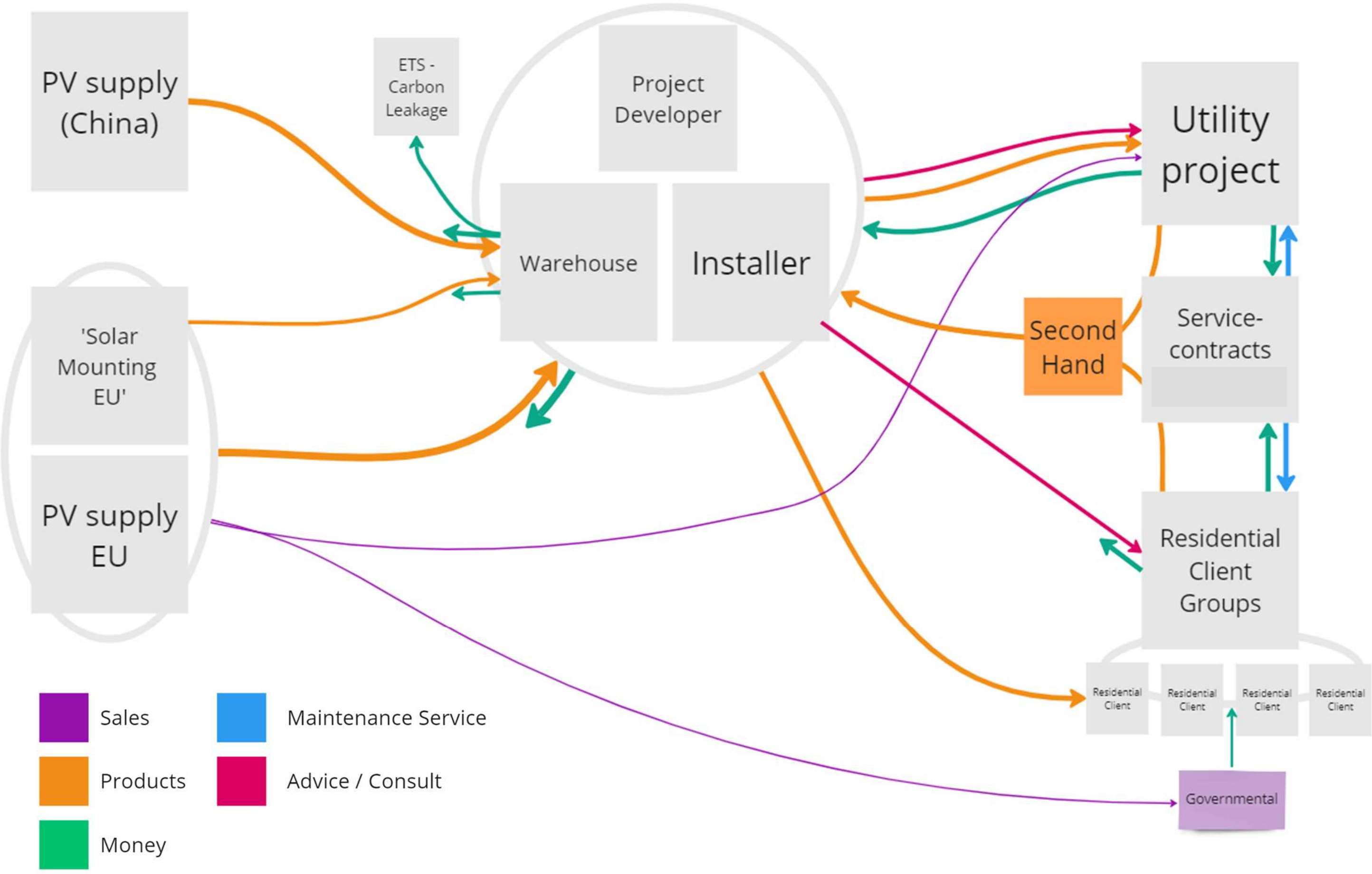


Figure 35: Schematic of value chains in the CE scenario. European mounting and PV supply collaborate to a single reuse product. A few all-round organisations are responsible for all install and replace services. Other service providers or invididuals can maintain and return product to their facilities.

H8 Scramble for Energy

Heavy cost-pressing competition on an diverse market of Solar Energy products, to offer affordable energy self-sufficiency in an international scramble for energy.

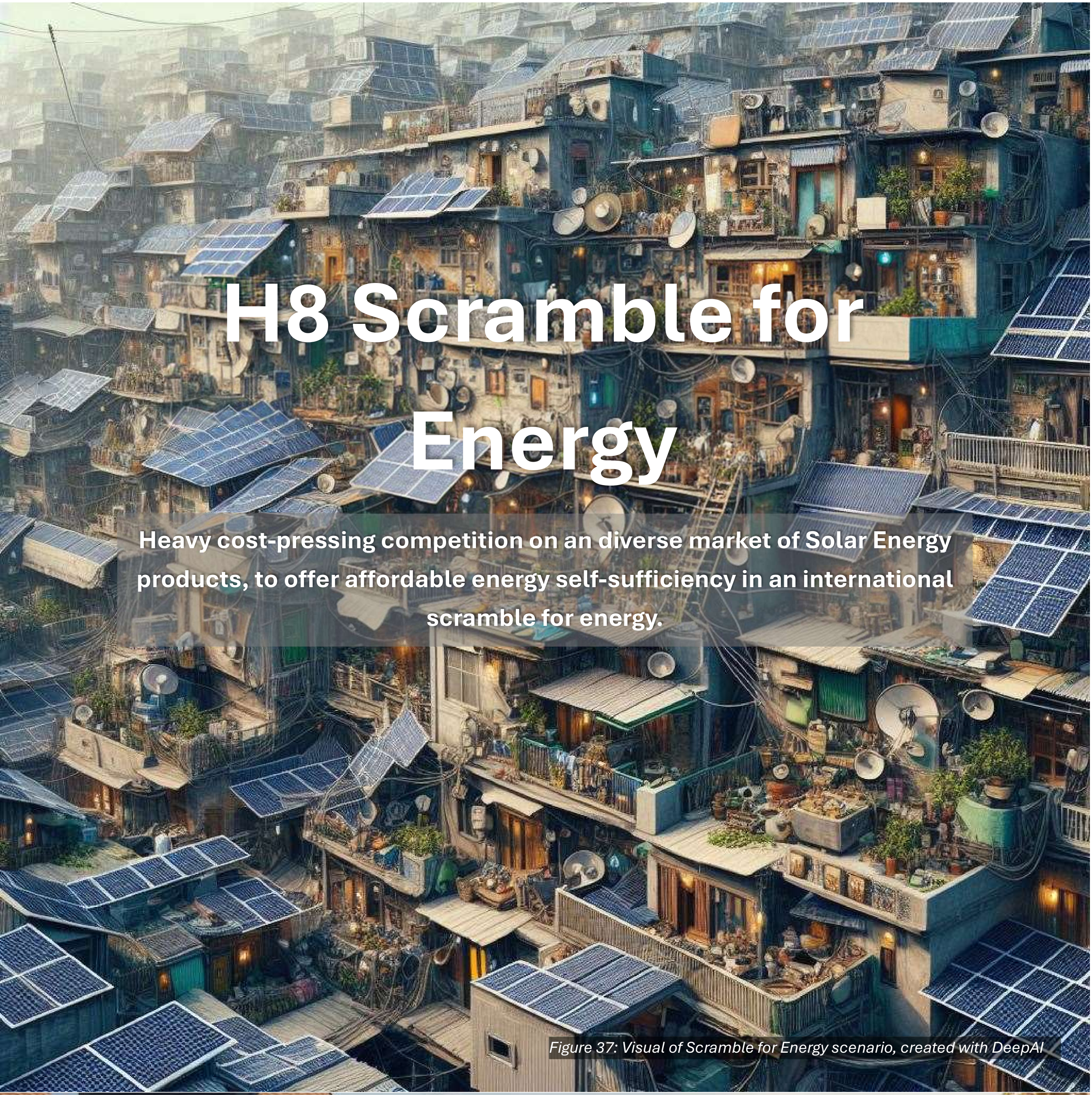
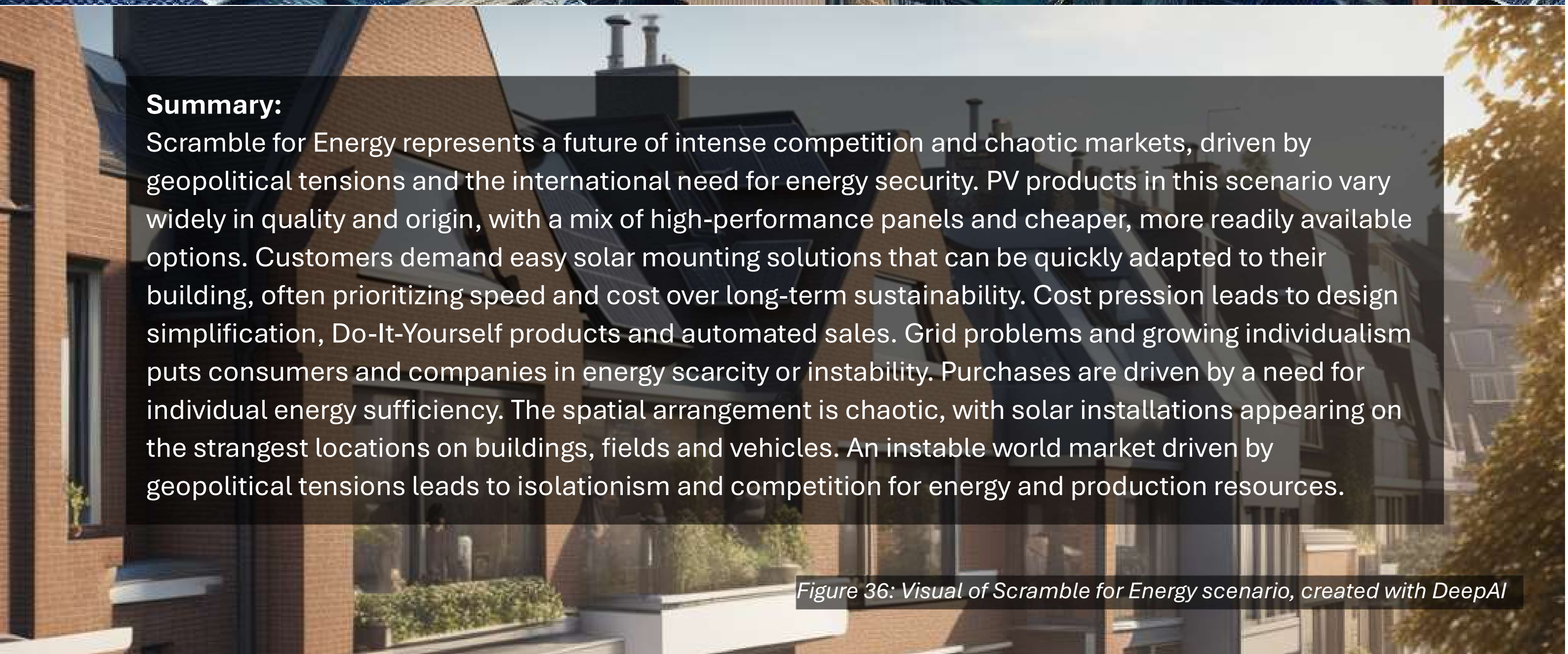


Figure 37: Visual of Scramble for Energy scenario, created with DeepAI



Summary:
Scramble for Energy represents a future of intense competition and chaotic markets, driven by geopolitical tensions and the international need for energy security. PV products in this scenario vary widely in quality and origin, with a mix of high-performance panels and cheaper, more readily available options. Customers demand easy solar mounting solutions that can be quickly adapted to their building, often prioritizing speed and cost over long-term sustainability. Cost pression leads to design simplification, Do-It-Yourself products and automated sales. Grid problems and growing individualism puts consumers and companies in energy scarcity or instability. Purchases are driven by a need for individual energy sufficiency. The spatial arrangement is chaotic, with solar installations appearing on the strangest locations on buildings, fields and vehicles. An instable world market driven by geopolitical tensions leads to isolationism and competition for energy and production resources.

Figure 36: Visual of Scramble for Energy scenario, created with DeepAI

8.1 Scenario Drivers

The schematic below shows how the eight key drivers of solar energy would develop into this scenario.

1. PV technology and products in market

Diversified PV products — Standardised PV panels

As a scramble for energy drives the demand for solar energy, basically any available form of PV, no matter quality, is accepted somewhere in the market.

2. Production location of PV products

Sign. European production — Intern. production and supply

Only critical materials limit the international production levels. As fossils stay as substitute, solar is price driven. Cheap labour countries produce and democratised societies buy from luxury to drop shipping.

3. Instalment projects and services

Collective Mass Instalment — Individual Diverse Sales

To enable the chaotic variety of solar products and price markets, the industry supplies a range from DIY to expertise mounting. A second hand market and AI consultation will make solar more affordable.

4. Answering energy needs in grid and price

Collective Energy Infra — Individual Energy Sufficiency

Energy inequality exists. Energy prices strongly fluctuate and the quality of solar differs per person. Only wealthy industries and customers afford stable energy, provided by energy management systems or as Energy as a service.

5. Geopolitical energy and product trading

Specific trading clubs — Free trade agreements

The solar industry is driven out of the EU through pricing. The dependency for energy on the international market is handled by creating a variable mix of imported fossils, renewables, and nuclear, to spread risks of supply.

6. Improved Sustainability of Production

Managing Scarce Resources — Circular Systems and Chains

As international independency is pushed through isolationism, all possible local production is strongly pushed for. Energy and material scarcity inherently stimulates minimising energy usage and material reduction.

7. Spatial lay-out priorities

Natural and Societal efforts — Maximising solar on roofs

The individual goal is for minimising costs and maximising solar energy. Any necessary and available location for solar will potentially be used, no matter other considerations.

8. Social acceptance and visibility sentiment

Social Friction — Proudly Visible

In a more polarised society, the inequality of energy and affordable solar creates social friction. In the visible field, solar products become a local symbol of inequality.

8.2 Product and Service

Product requirements

As availability to solar energy to all is the priority, the Archipelagos scenario steers on a highly cost-price competitive market, both for PV panels as for mounting solutions. The market control by safety standards is minimised to what is purely necessary. Besides on price, products differentiate in quality and convenience for installing. And mounting has to adapt to the wide supplied types of PV. Products for utility and residential differ strongly due to its mass and project-based versus custom and home-serviced character. Within new constructions, BIPV can become a price-relevant easy integration of energy needs, deleting additional installing costs, as panels become roofs and facades.

Approaching solar mounting from mass affordable and adaptable perspectives, while creating a qualitative product-line, the product requirements will be added and modified to:

Requirement	Value/ Aspect	Purpose
Installation	Failure-proof/Easy	Installation by (migration-)workers / DIY
Weight of structure	18-20 kg/m2	P90 product fit, as cheap mass product
Mounting	Most panels, most roofs	Over dimensioned ballast & variable clamping options for most panel sizes and roof structures
End of Life	Relocate	Energy as a Service, rental / temporary solar
Material Production	Waste-based and/ or independent	Minimising international dependency by using local waste composite or mass available steel
Project	Automation	Minimising work and failure risks
Safety	AR/AI quality check	No certified personnel, but certified assessment

Table 7: Abbreviated list of requirements for SfE product, full list in Appendix A

Product

For this scenario, I designed an panel-corner mounting method for any panel size, that will interconnect a field through sheet-metal form fits. See the next page for a total product view.

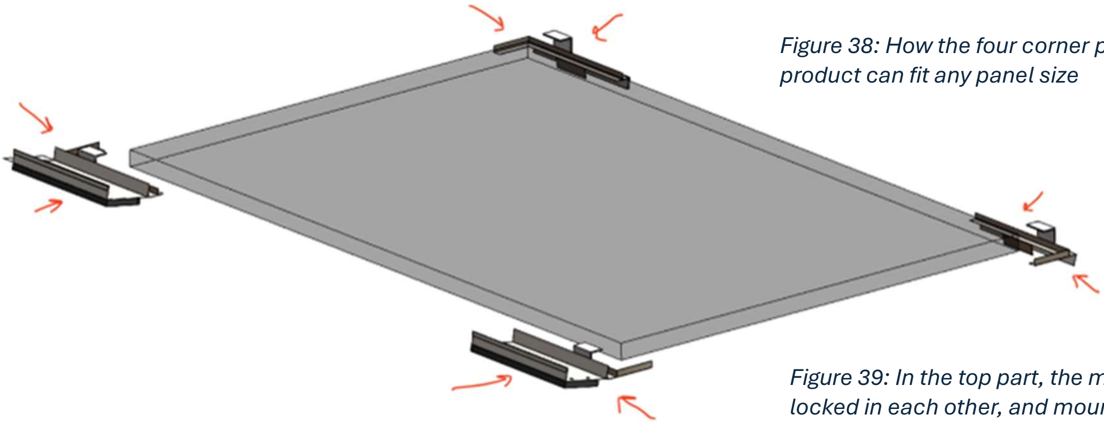
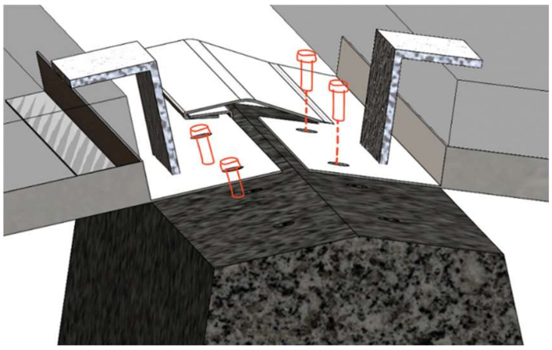


Figure 38: How the four corner pieces of the SfE product can fit any panel size

On the lower foot, the connection is secured by the material friction of the metal slid, and the weight of the ballast. The hi se

Figure 40: For an east-west orientation, the mounting pieces on one side connect to those of the next panel

Figure 39: In the top part, the mounting pieces are locked in each other, and mounted to a ballast pole



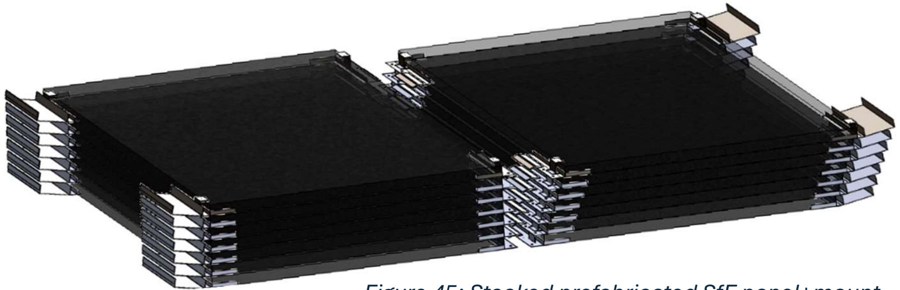


Figure 45: Stacked prefabricated SfE panel+mount

When preassembled on a batch of solar panels, the sets can be stacked seamlessly, adding just a 1mm stacking height from the sheet metal.

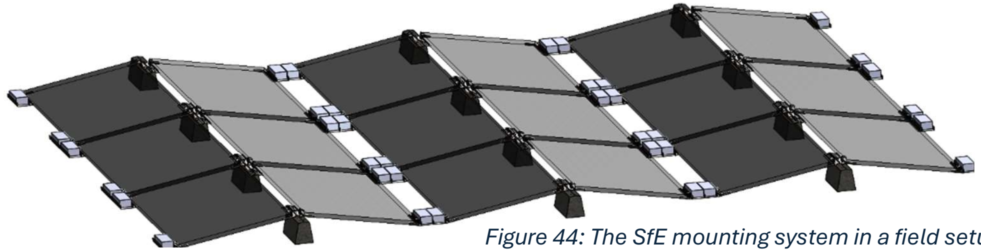


Figure 44: The SfE mounting system in a field setup

The products configuration shows minimal potential in adjusting ballast weight. The weighted high poles' function as small water tank offers for a minor adjustment, but will create a range up to a ~ P90 fit, for general usage in non coastal areas.

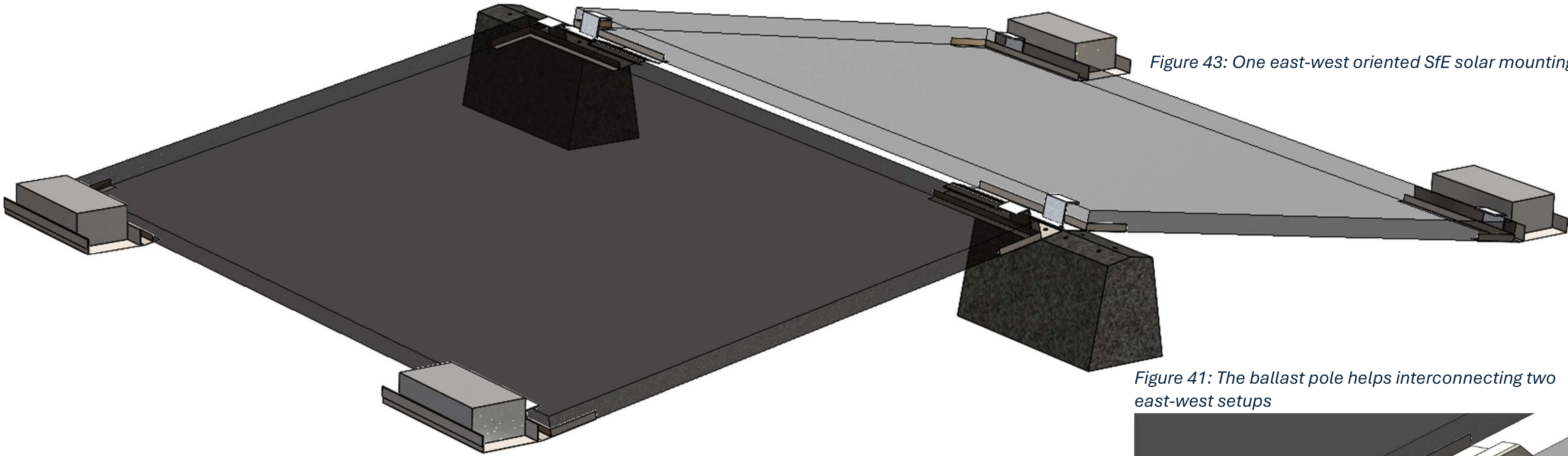


Figure 43: One east-west oriented SfE solar mounting setup

Figure 41: The ballast pole helps interconnecting two east-west setups

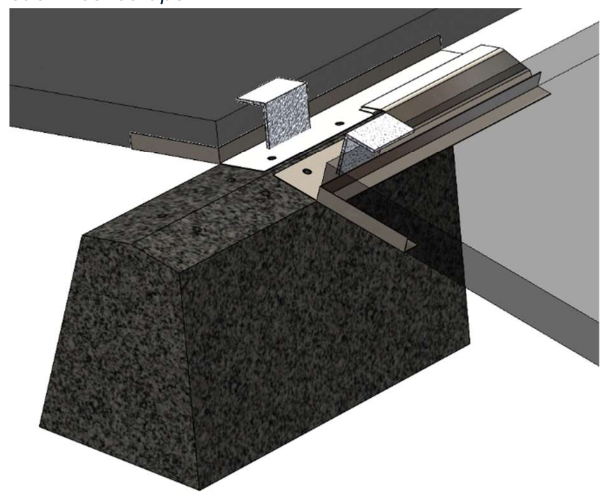
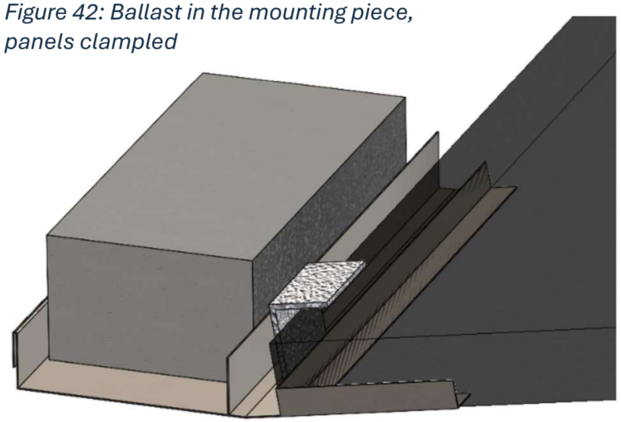


Figure 42: Ballast in the mounting piece, panels clampled



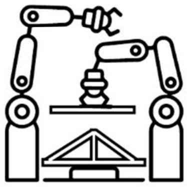
Existing mounting systems use a similar method of four clamps in the corners on the vertical side. Although the (middle of the) panel has to endure the same weather/wind forces, my design also leads the mechanical forces of its own weight and interconnected structure through the panels frame. It might not seem a preferable fit for the durability of the solar panel, but disregards fits the scenario's context for efficiency over durability. Even more, a few limitations on the allowed circumstances are accounted for in this P90, but definitely not all-enabling design.

Services and supply chain

On the services for affordable solar energy in utility and residential, the supply chain is optimised for cost-efficient sales, instalment and logistics:

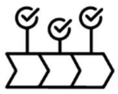
In the ***Production*** phase, all production companies solely use the cheapest available constructive materials and automate the process to minimise human labour. Although unpreferred from an international independency need, cheap labour products from developing countries enters the market through drop-shipping and producers outsourcing labour for cost pressive reasons.

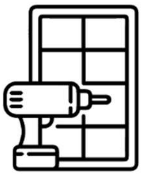
By automated ***Prefabrication (or Preassembling)*** of the product for utility purposes, the manual mounting process on the roof itself is minimised. As the specific PV and mounting needs for small-scale residential sales will constantly differ because of the chaotic individual market, the assemblage of mounting and panel is simplified for individual one-time DIY purposes.



For ***Consultation***, there will be use of virtual assistants and AI consultation of calculators, all in service for matching power needs and installed capacity. For efficiency reasons, all easy implementable structural situations get assigned a cheap P90 product with an simplified over dimensioning ballasting.

The ***Carbon and sustainable transparency*** is only necessary to comply to policies, as governments demands energy efficiency and domestic efforts. All ***Transport*** practices are planned in batches from production to customer directly, as minimal distances and cutting transport costs are deployed. This follows the societal rise of drop-shipping and direct customer sales.





For ***Installation*** practices, a utility project developer will apply cheap labour on the construction of mounting systems as simple and failure proof as possible. Quality checks are automated. A residential solar mount is instructed via gamification and screens, so that a one-time execution goes smoothly. Camera, AI and build-in tech performs safety and quality checks.

Afterwards, ***Service and Maintenance*** is simplified for the user, as minimal system failure is an aspect of the bought quality, and a personal responsibility. Utility service focuses on integrated or outsourced quality checks and warranty and insurance claims. As a market reaction, **Energy as a Service** companies offer a resolution of energy insecurity for the wealthy and certain industries.

For the ***End-of-life,*** the first step is resell PV and mounting together or separately on the free individual market, lowering public entry costs, without warranties. For further ***Recycling***, all mounting systems will be demolished and taken in the general (building-) waste stream management. The government has set up a unified recycling facility for recycled critical materials and destruction of residuals.

8.3 Sales and Value Chains

The scramble for energy creates a complex and chaotic sales market. It could behold singular budgetary customers, providers of 'energy as a service', bulk resellers and industrial clients.
In this scenario, the installation market is driven by cost-price and availability. Figure 46 shows a simplified version of the many complex value chains.

The sales market is focused on commercial and private projects for self-sufficient energy production. Sales demand comes from energy needs, and is marketed towards some domestic choices, resulting from the paradigm on 'international independency'. The government is constantly keeping domestic companies afloat, to help supply for the massive demand, but competition with the international cheap labour market is hard.

<u>Supply</u>
Utility mounting products are bought in mass batches by project developers, constantly picking the cheapest offers, with a challenge for remaining a consistent quality and brand-image. Anyone who wants to enter as producer or installer of solar mounting can compete for a customer segment in enabling solar, especially via the (online) warehouses for residential customers.

<u>Clients</u>
Utility clients are focused on gaining self-sufficient energy production, including strong stability and back-up plans. This leads to a high demand on maintenance and service, and strong energy management consultancy to create a stable energy-plan out of all possible products and services.
Residential clients are on their own. Here, quality of product and service differs even more. Home owners consult themselves through the internet, and make subjective decisions on the best product fit for them. More wealthy customers afford trustful product consulting, warranties, insurance and more. The margin on products is earned by dividing quality from the mass.

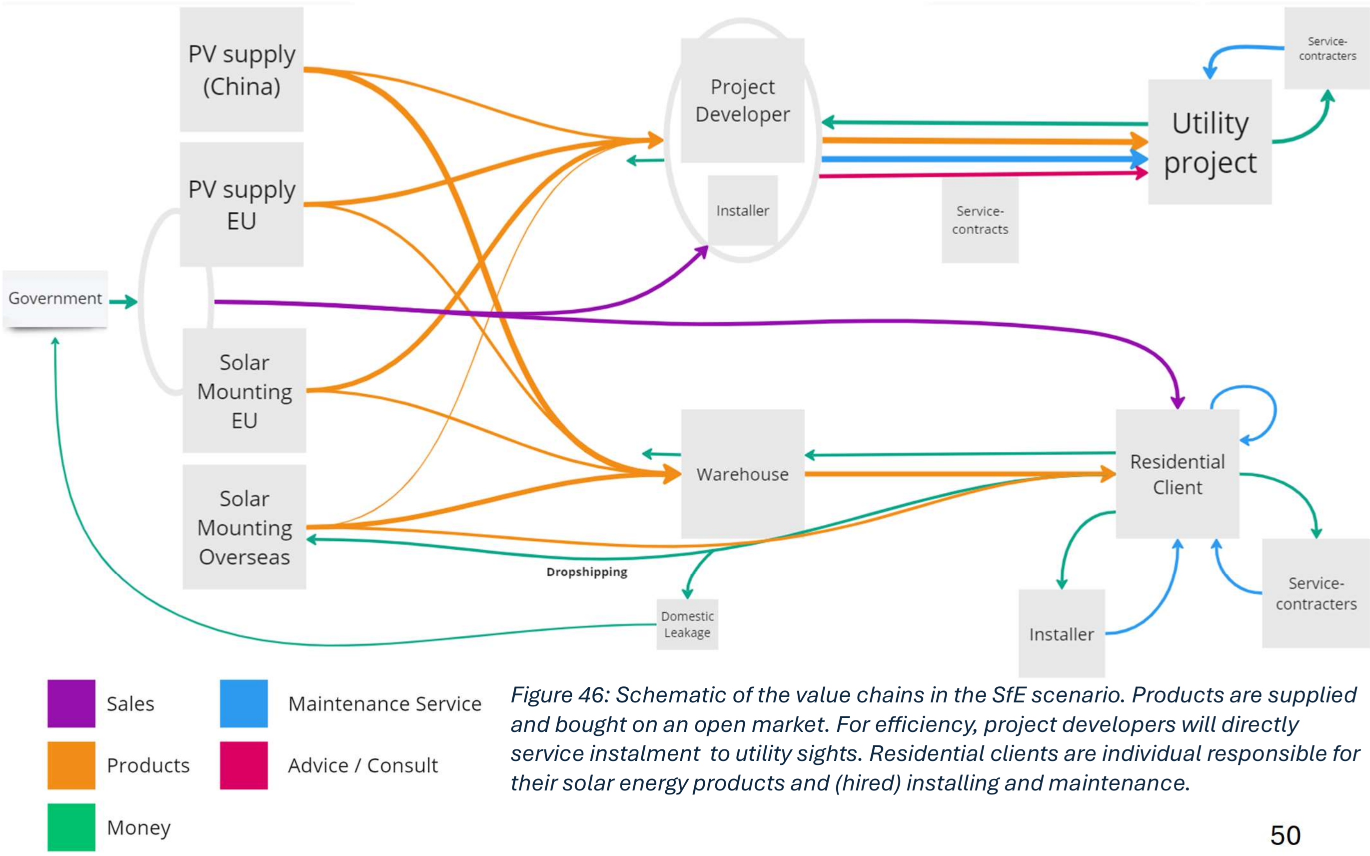


Figure 46: Schematic of the value chains in the SfE scenario. Products are supplied and bought on an open market. For efficiency, project developers will directly service instalment to utility sights. Residential clients are individual responsible for their solar energy products and (hired) installing and maintenance.

H9 Power to People

Socially repurposing and allocating available Solar Energy, whilst improving domestic wealth and climate adaptation

Figure 48: Visual of Power to People scenario, created with DeepAI

Summary:
Power to People emphasizes a decentralized, community-driven approach to solar energy, where solar energy supports local wealth. This scenario envisions a market where small-scale batches of contracted solar panels are distributed via tenders. Developers of solar projects match local energy requirements to additional social/nature benefits created by the mounting system. Customers include community cooperatives and local governments. Motivated by energy equality and local wealth, there is a strong focus on local production and materials, and systems designed for easy maintenance and repair. Spatially, it creates multifunctional spaces, where solar installations are mixed with green or blue roofs, bringing many local benefits as renewable energy, water management and biodiversity. With solar panels integrated into neighbourhoods, community buildings, and public spaces, it sets up small scale energy sharing. A bottom-up approach to energy infrastructure and climate adaptation.

Figure 47: Visual of Power to People scenario, created with DeepAI

9.1 Scenario Drivers

The schematic below shows how the eight key drivers of solar energy would develop into this scenario.

1. PV technology and products in market

Diversified PV products — Standardised PV panels

As the available solar products are centrally imported, the type and dimensions of PV is depended of facilities of contracted supply. Central demand steers each product into a stable and standardised version.

2. Production location of PV products

Sign. European production — Intern. production and supply

Although late investments in EU production, most solar is imported. By contracting suppliers, organisations can get some order on PV form and quality. Small EU production starts up-scalable technologies and urban mining.

3. Instalment projects and services

Collective Mass Instalment — Individual Diverse Sales

The solar mounting serves the variety of contract produced panels and PV technologies, by aligning mounting and installation per requirements of assigned batches. Best serving local wealth/nature wins over tenders.

4. Answering energy needs in grid and price

Collective Energy Infra — Individual Energy Sufficiency

From social equality needs comes the drive for community based solar sharing. Humanising the energy transition results in organisational solar projects for local collective sufficiency. Public essential buildings gets priority.

5. Geopolitical energy and product trading

Specific trading clubs — Free trade agreements

The EU struggles to become energy independent. Besides a focus on energy savings, the government takes a grip on proper distribution and contracting of available international energy and stimulates local industries and markets.

6. Improved Sustainability of Production

Managing Scarce Resources — Circular Systems and Chains

With energy and material scarcity, a drive for efficiency in production grows. An important focus is on effective use of local waste materials and products, in domestic sufficient production.

7. Spatial lay-out priorities

Natural and Societal efforts — Maximising solar on roofs

Solar is strategically installed on the best local roofs / land available, sharing the optimised cumulative energy supply among (local) society. Install practices are smartly combined with biodiversity or water management improvement.

8. Social acceptance and visibility sentiment

Social Friction — Proudly Visible

Solar panels become a symbol of sharing and equality. As a project is won over for its additional local benefits, solar is accompanied by societal wealth.

9.2 Product and Service

Product requirements

As fair and equal distribution of energy within society would become the paradigm, government and business work on an allocation/tender system for the available (contracted) solar panels from market, coming in a few standardised sizes and quality. Within each to be installed solar project, we will be searching for the best match in (available) PV type, micro-grid/hub location, energy needs and societal prosperity.

Approaching solar mounting from adaptability and societal prosperity, the product requirements will be added and modified to:

Table 8: Abbreviated list of requirements for PtP product, full list in Appendix A

Installation	Customised Ease	Customisable product that is installed in standard instructible steps. Installation by local groups.
Weight of structure	≥ 20kg/m2	Quality of product is priority. Not all roofs needed.
Mounting	Project adjustable	Adjustable to Project-based dimensions & quality
End-of-Life	Connection points	Allow base structure to mount in added products
Material Production	Waste-based and/ or low-carbon steel	Boosting local industries and wealth, minimising dependency and climate impact
Project	Expert bio/water	Expertised personnel in local nature, biodiversity and water management
Ballast material	Water, greenery, wood	Multi functional function of water management, biodiversity or additional products.
Installation	Customised Ease	Customisable product that is installed in standard instructible steps. Installation by local groups.

Product

For this scenario, there will be a high product variety for specific nature, water and societal benefits. Among others, I redesigned the qualitative mounting system 'Nova'* of Sunbeam into a flexible product structure for 'open' east-west configuration, including several climate beneficial elements.

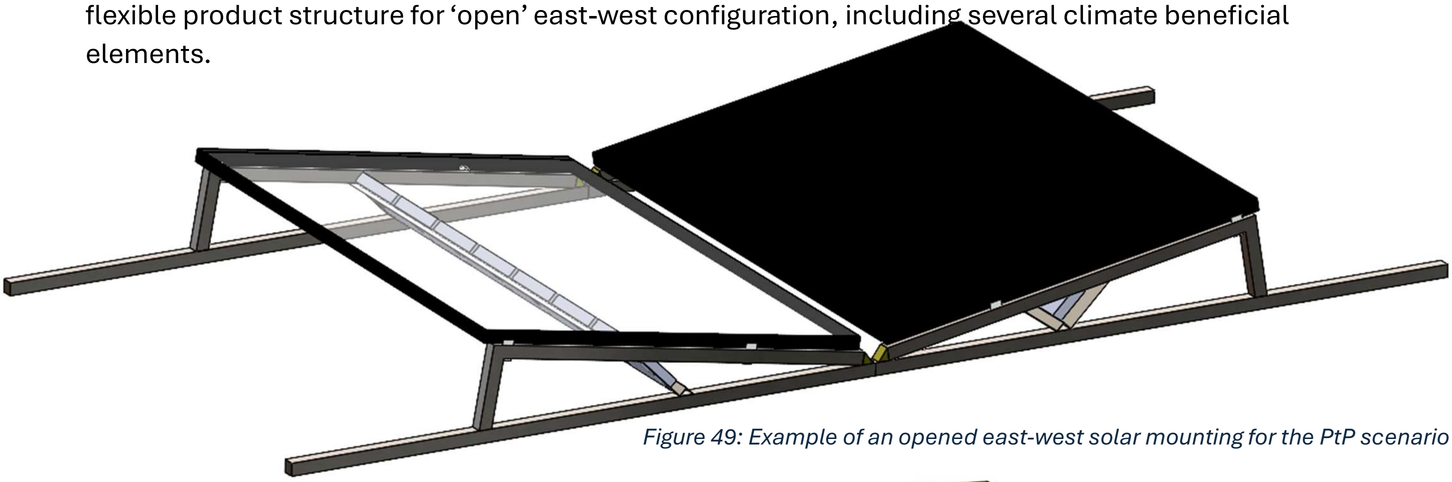


Figure 49: Example of an opened east-west solar mounting for the PtP scenario

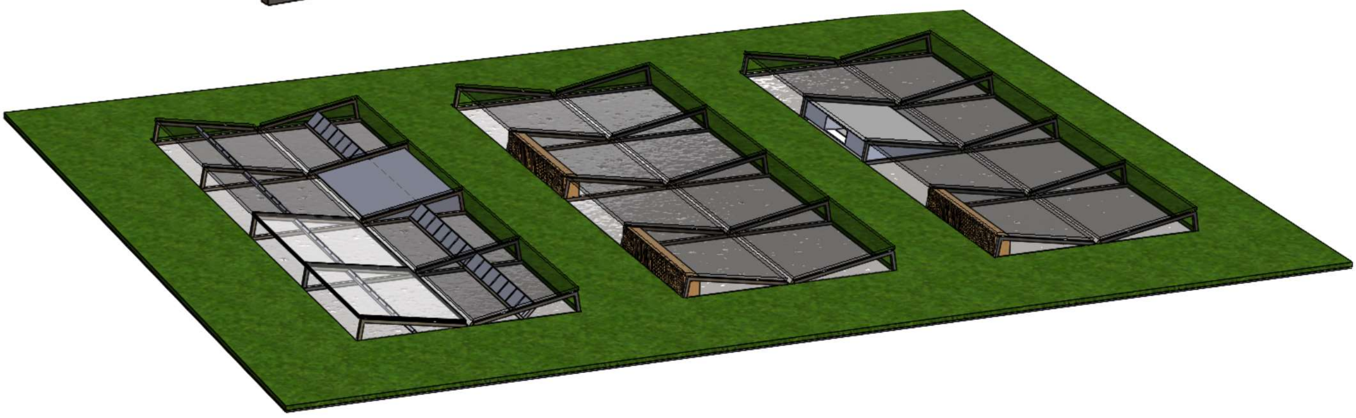


Figure 50: An examplary field of solar installations, combined with sedum roofs and additional mounting products

Figure 54: Ballast creating a safeguarded space for electronics

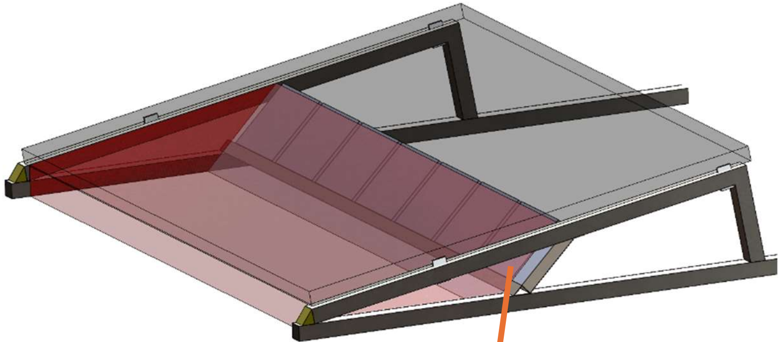
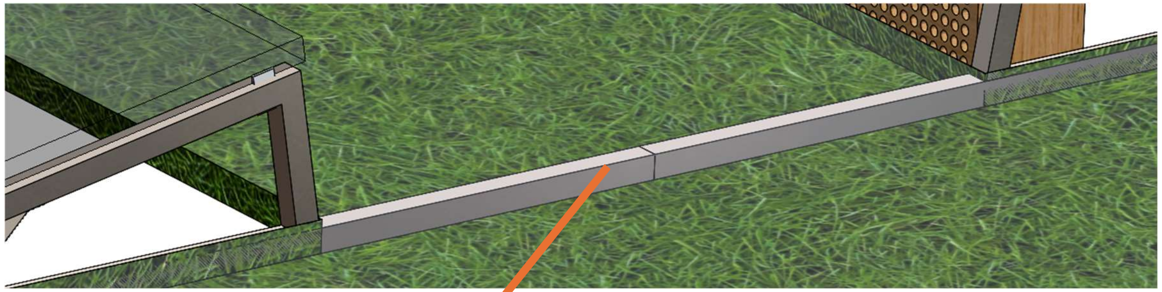


Figure 53: Interconnecting the solar mounting systems below the sedum, to uphold interconnected strength



The open east-west construction makes room for greenery and animals. Whilst the ballast construction encloses a secured space for electronics.

For ballast minimising, the structure is still interconnected beneath the greenery or gravel.

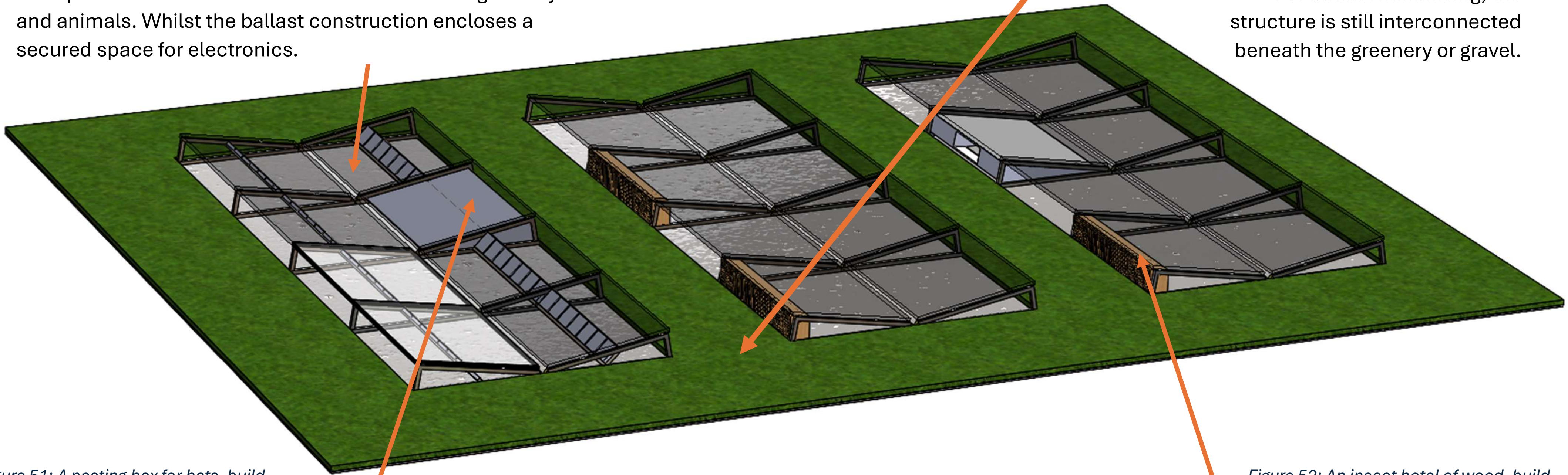


Figure 51: A nesting box for bats, build into an open solar mounting construction

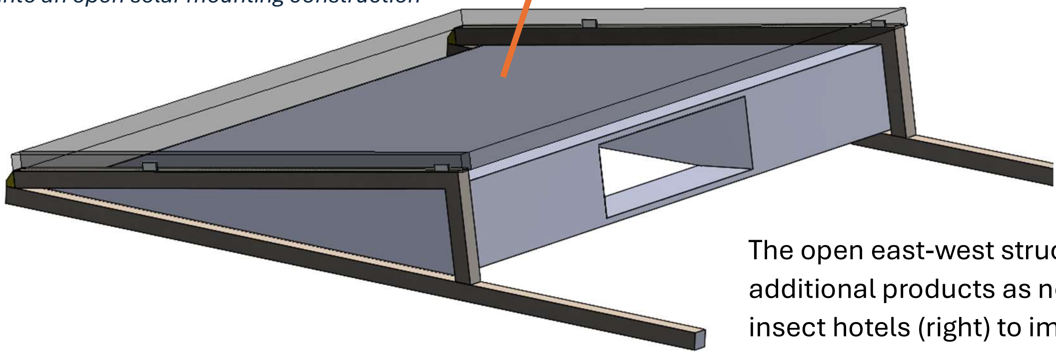
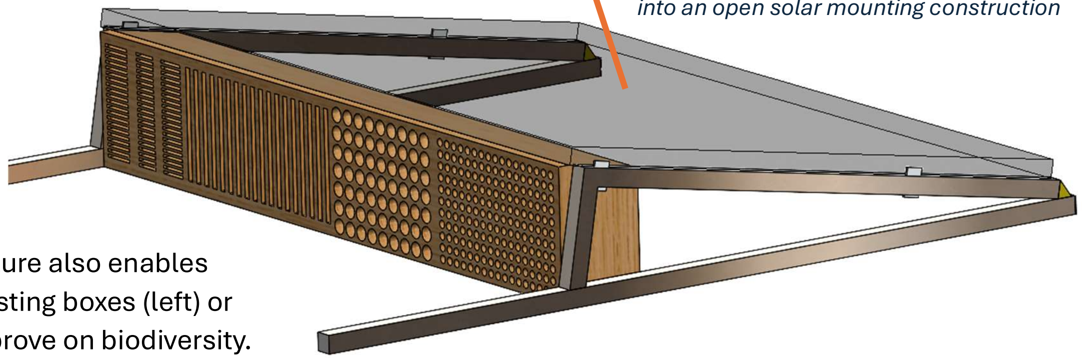


Figure 52: An insect hotel of wood, build into an open solar mounting construction



The open east-west structure also enables additional products as nesting boxes (left) or insect hotels (right) to improve on biodiversity.

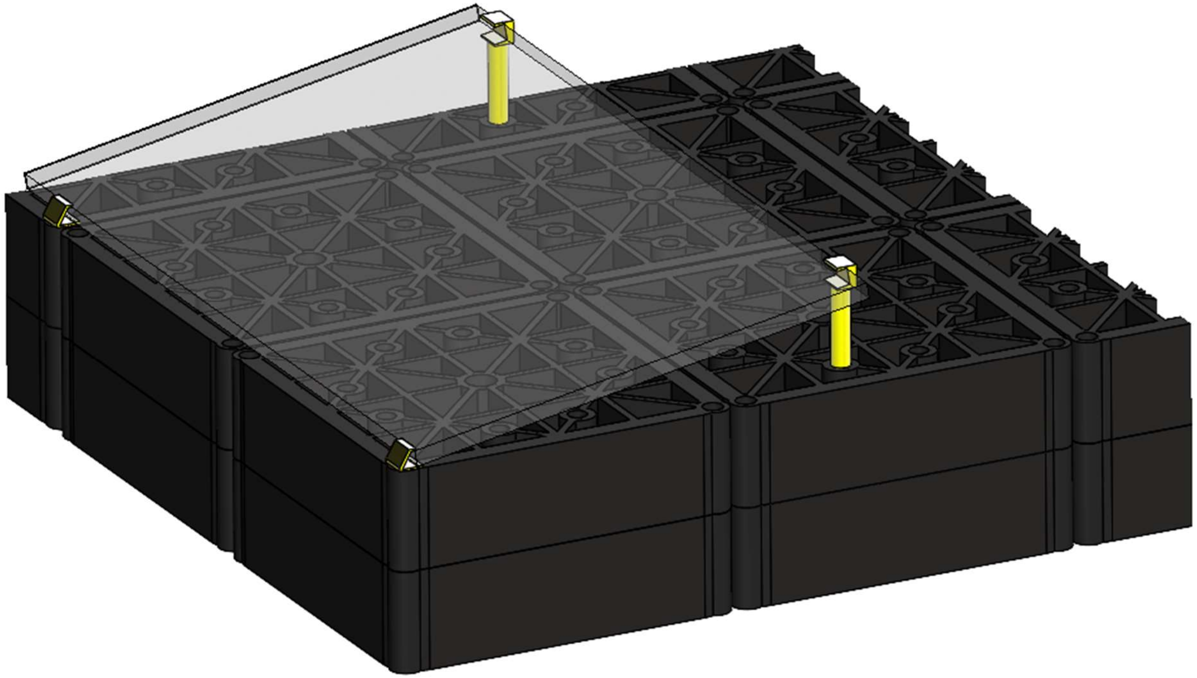


Figure 56: Single mounting clamps and poles, flexible mountable into a field of infiltration crates

Another product redesign* shows the potential to integrate roof infiltration crates for water management and solar mounting structures. It promotes multifunctional use of roofs and is even combinable with the previous design suggestions for greenery and biodiversity.

This design uses the infiltration crates as interconnecting base-structure and ballast.

This minimises the material resources used for installing solar, upon facilitating infiltration crates as climate adaptive measurement.

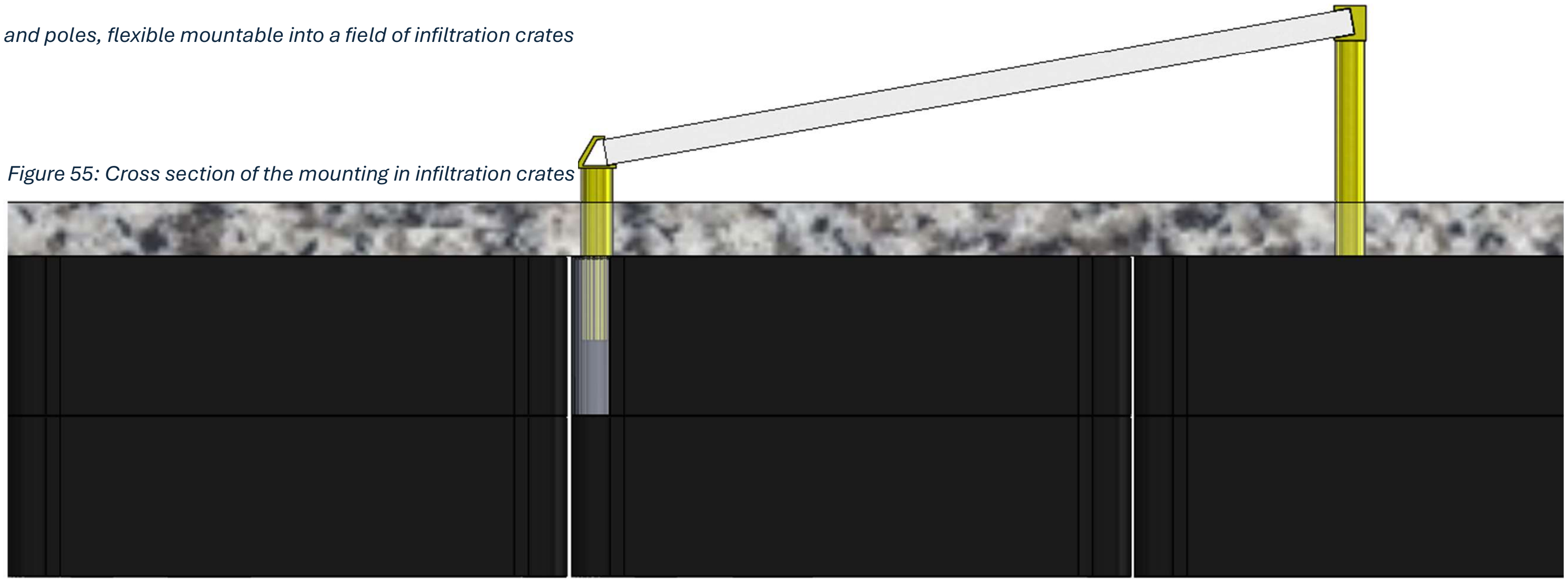


Figure 55: Cross section of the mounting in infiltration crates

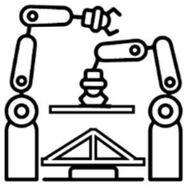
*Both designs make use of existing proven *clamping* and *structuring* solutions widely applied in the solar market. As these design functions can simply be redesigned, I did not design or draw those functions in detail for scenario support.

Services and supply chain

The services that are provided to produce, install and take care of these solar mounting solutions are, through the supply chain, focused on altruistic and effective improvements.:

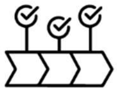
As the ***Production*** phase will more and more be relocated to domestic and European industries, the process is balanced between efficient automation (costs) and manned production as local jobs.

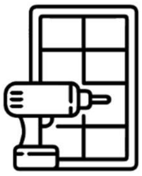
By automated ***Prefabrication (or Preassembling)*** of the product for utility purposes, the manual mounting process on the roof itself is minimised. As the specific PV and mounting needs for small-scale residential sales will constantly differ because of the chaotic individual market, the assemblage of mounting and panel is simplified for individual one-time DIY purposes.



For ***Consultation***, project developers will create an own segmented expertise regarding common allocated PV types and public valued mounting solutions, winning over the best match.

The ***Carbon and sustainability transparency*** is mostly focused on local effects in CSR and the positive impact of solar, thus disregarding supply chain details and small side-effects. All ***Transport*** of allocated foreign PV and solar mounting materials is done by project developers. It has to comply to energy efficiency rules and rising emission-free zones.





The ***Installation*** practices are performed by a mix of specialists and local workers. Although mounting systems differ in installation processes, the processes are optimised for optimal workers conditions and qualitative results, using augmented reality and 'learnstriments'.

Afterwards, ***Service and Maintenance*** gets more complicated, as these solar projects all embed different functionalities and mounting. Service providers split in PV-type specialists and mounting specialists, often working together on serving lots of mixed projects.

For the ***End-of-life***, the first step is re-allocating PV and mounting together or reselling on the open market.
When ready for ***Recycling***, waste-streams become of increased value for retrieving (critical) materials and supplying domestic productions. Therefore, mounting systems are optimised for separation and closed loop recycling.

9.3 Sales and Value Chains

In the *Power to the People* scenario, the installation market is driven by availability and project allocation. The sales market is focused on public and cooperation projects for local energy sufficiency. As a result of internationally contracted PV supply and minimal available overstock, the market transformed to adaptive and prosperity services. Planned solar projects gain PV allocations / subsidies by inclusion of solar energy in (community-) initiatives for energy equality, climate adaptive multifunctioning and social purposes. The contracting sales process is illustrated in the lower part of the value chains in Figure 57.

<u>Supply</u>.
By offering the best balance of costs and the best project targets in added value for society, the project developer wins the right to contract a certain batch/period of foreign solar production supply.
The solar mounting industry provides warehouses with a product mix of biodiverse, water-management or social wealth solutions that bring this multifunctional prosperity.
As project developers win over PV, they again negotiate/consult with warehouses for supply of products and instruct their personnel to install with the right product mix, for the granted Public Project.

<u>Clients</u>
The project developer/contractor focuses on winning over PV-allocation and installation for a registered client that wants to apply for a utility and/or public solar project. So, the sales process goes in two ways; winning over the management of a project, and winning over the allocated PV for it.
In the upper parts of the figure, the earlier 'scramble for energy' aspects of the value chain are still in play. Besides the main new prosperity market, sales of small individual projects takes part via warehouses, buying up second hand or free marketable PV and selling to residential clients affording extra local energy sufficient products and services. Just as there are project developers working with un-allocated PV stock to serve wealthy utility projects.

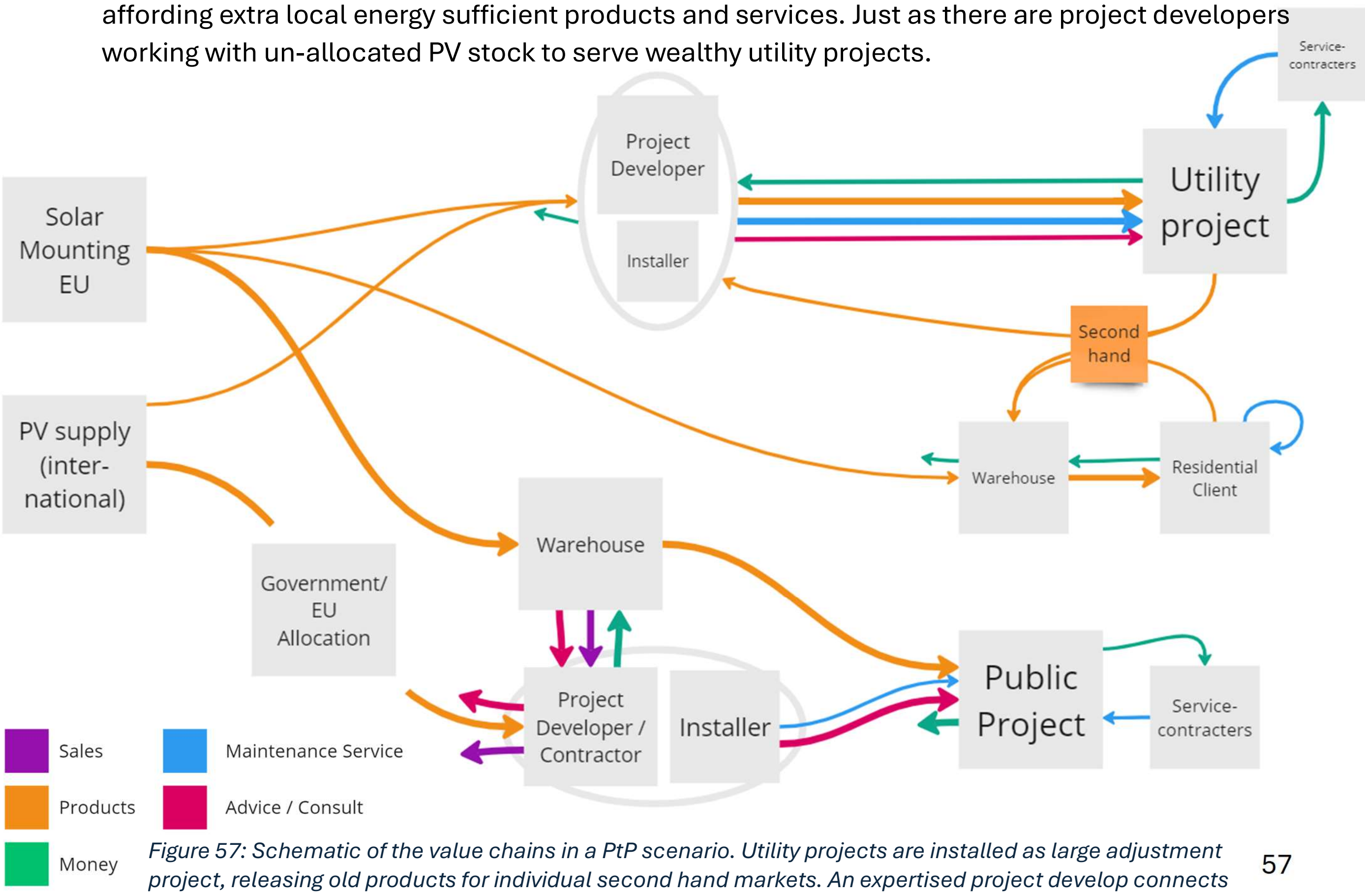


Figure 57: Schematic of the value chains in a PtP scenario. Utility projects are installed as large adjustment project, releasing old products for individual second hand markets. An expertised project develop connects governmental tenders and communities and installs an adjusted mix of beneficial products, provided by warehouses.

As phase:

Stakeholder Assessment
Identify Accepteds Identify Impossibilities Identify Yet-To-Be-Played-Outs

10. Stakeholder Assessments

To evaluate the four product-scenarios, I conducted a stakeholder assessment to identify interests within the solar mounting industry. The core research question in this assessment was:

RQ: 'Which consumer and stakeholder interests will support, obstruct, or drive changes in the development of the solar mounting industry toward one of the constructed scenarios?'

This research question is in line with Fahey & Randall's (1998) steps to identify yet-to-be-play-outs (change), accepteds (support) and impossibilities (obstruct) of an industry scenario.
For each scenario, I researched these interests from their responses on the designed product, on the constructed end-state and on the accommodating development of key drivers. A complete description of the conducted research plan is found in Appendix O.

Method

The stakeholder assessment involved a three-hour group session with three key representatives from the solar mounting industry:

- An R&D manager/designer of solar mounting (from within the graduation organisation)
- An executive of a Installer's project developer for small sized utility installations
- An executive of a warehouse/reseller for installers products in energy/warmth

The assessment combined surveys and facilitated discussions about the developed product scenarios, yielding both quantitative and qualitative data. The qualitative data consists of written and recorded feedback. An affinity diagram was used to process the feedback.

My research included two planned moments of participant feedback:

- *1. Stakeholder interests per product-scenario*: an survey and group discussion on the specific presented product-scenario and its associated stakeholder support, obstructs and required changes. Obtaining insights on the viability.
- *2. Scenarios comparison for the industry*: an survey on the relative desirability and feasibility of the scenarios, and the development focus for stakeholder and industry to realise such scenario.

Data and Interpretation
The processed results of feedback 1 are listed in paragraph 10.1. They are used as qualitative input for the road mapping phase, to understand stakeholder needs in clients and partner setups.
The processed results of feedback 2 in interests comparison are presented in paragraph 10.2, and help set up conclusions for the industry's most likely future direction and driver developments.

10.1 Scenario Interests

From the first two numeric questions in Table 9, we can conclude how realisable the four constructed scenarios are, when looking at market cooperation towards realisation. The first numeric of 'interest' indicates the stakeholders willingness to do business in that eventual end-state. The second numeric indicates how much effort it takes from these stakeholders to change its business to fit this end-state. The 'focus of development' parts show the necessary change of business and product-use-system for the stakeholder internally, and for its role for the industry.

Table 9: Stakeholder Interest Comparison

Scenario	**Circular Energy**	**Standardised Mass Energy**	**Scramble for Energy**	**Power to People**
Stakeholders Interest	failure – success 1 2 3 4 5 6 7 Inst: 1; WH: 2; R&D: 6	failure – success 1 2 3 4 5 6 7 WH: 2; R&D: 5; Inst: 7	failure – success 1 2 3 4 5 6 7 Inst: 3; WH: 6; R&D: 6	failure – success 1 2 3 4 5 6 7 Inst: 5; WH: 6; R&D: 7
Change intensity for Stakeholder	stable – rebuild 1 2 3 4 5 6 7 Inst: 4; WH: 7; R&D: 7	stable – rebuild 1 2 3 4 5 6 7 Inst: 1; WH: 2; R&D: 5	Stable – rebuild 1 2 3 4 5 6 7 Inst: 1; WH: 3; R&D: 4	stable – rebuild 1 2 3 4 5 6 7 Inst: 5; WH: 6; R&D: 6
Focus of development for stakeholder	**R&D** Collaboration with other big construction companies, developing modular product portfolio. **WH** Change from product to service. New business model. **Inst*** Upscaling logistics capacity and adding services as cleaning/maintaining	**R&D** Consolidation. Taking over or outcompeting the competition. **WH** Consolidatie, lean and mean. Invest to become the big remaining player. **Inst*** Optimising efficiency of existing install processes. Collaborating for capacity	**R&D** Continual R&D as reaction on changing market needs **WH** Continuation of product portfolio management, knowledge and advice **Inst*** No share in installation, only expertise relevant failure-fix, services etc.	**R&D** Collaboration with water, greenergy, biodiversity specialist **WH** Grow knowledge, project management and broaden product portfolio **Inst*** Grow expertise and knowledge on new segments as nature, water ánd on many products.
Focus of development for industry and society	**R&D** Collaborative and adjusted production facilities **WH** Standardising. Integration and collaborations. **Inst*** Centralising infra capacity and wages that support reuse-systems	**R&D** Upscaling all production and services **WH** Optimised upscaling. Create standards and governmental laws. **Inst*** Internationally optimising and securing value chain suppliers and tasks	**R&D** Quality management, responsibility and warranties. Monitor emissions. **WH** Reduce production costs, increase B2C market and create minimal norms **Inst*** Service, EMS and products to support individualistic energy market and increased net congestion	**R&D** Continually combine new insights and policies **WH** Sustainable integrated products and materialism **Inst*** Growing consultancies and policies on biodiversity, nature and more

*The written feedback of the installer was incomplete; conclusion are based on input in the group discussion and written feedback on the individual scenarios.

There are two main conclusion that can be drawn from this research:

- 1. The scenarios of 'Standardised Mass Energy' and 'Scramble for Energy' are, in total, similarly ranked as successfully fulfilling interests and being relatively easy and stably implementable.
- 2. The scenario of 'Power to People' is best valued to pursue the interest of all stakeholders interviewed. However, it takes the most intense rebuild and change efforts to get the solar mounting industry to this state.

"Headed for the Scramble for Energy scenario" – (paraphrased from all respondents)
What is interesting about the first conclusion is, that when observing the existing market and interpreting the stakeholder discussions and interviews, the current market seems to be on the crossroad between both 'Standardised Mass Energy' and 'Scramble for Energy', not yet changed towards either of them.
The reluctance to choose one or the other could be explained from the opposite interests of project-developers/ project-installers versus warehouses/resellers. The first is benefited by a mass-scale installing process and low-cost standardised procedures, while the other is benefited by product differentiation and margins. But, because of the latest governmental drop of subsidies and guidance, the 'free market' is stimulated. Together with inventions on home batteries, all participants see reasons to believe the 'Scramble for Energy' scenario is unfolding.

"Power to People is the nicest scenario" – (paraphrased from all respondents)
What defines conclusion two, is that a change towards the 'Power to People' scenario is of great interests for all three responding stakeholders. However, for the industry's development, the biggest challenges are in the intensive change of knowledge, products and necessary collaborations with new knowledge partners. Those are intensive developments, but all within possible scope when "society and government guide norms on which positive impact is desired where".

10.2 Support, obstructions and changes per scenario

Table 10 to 13 show an overview of the most influencing support, obstruct and change structures within the stakeholders. I have selected and summarised these insights from the qualitative input data through affinity diagrams in Appendix P.

Table 10 shows that the *Standardised Mass Energy* scenario is potentially supported by the current development of bigger sales projects and preference for standardised and all-in-one mounting systems. What obstructs this scenario is the lack of (control on) resources in the value chain. And the consolidation that results from projects scaling up will mostly eliminate margins for wholesalers. For scaling up, the stakeholders desire a method of safeguarding the international dependencies. They also need a qualitative change of their business into a mass service system. The quotes show a concern in the unmanageable scale of this scenario.

What we can learn from Table 11, is that for all stakeholders, the existing support for the *Circular Energy* scenario is the intensive demand for qualitative design, instalment and reuse execution. But although there is differentiation in executional quality, the lack of product distinction dissolves market forces and so stops the innovation of product and service. This obstruction would result in higher costs for the customer. The industry therefore needs collaboration and stimulation to become service based and grow logistics. The quotes show a concert for a necessary economic and geopolitical context.

Standardised Mass Energy

	R&D	Warehouse	Installer's Project Developer
Support	Large volumes, sales and mass means price optimisation	Big sales, distribution and priceable tasks. Simple portfolio.	Mass amount of work. Standardised process, simple portfolio
Obstruct	Heavy competition, hard to include human rights and emissions	No margins in standard portfolio. Consolidation risks. No mass acceptance.	Insufficient (human) resources for mass cost pression. Single customer = no price competition
Change	Needs international collaborations	From supplier to service provider. Change of business.	Upscaling qualitative install standards, projects and logistics

Table 110: Indicated supporting, obstructing and change factor for SME

Quotes

"So in order to fulfill energy needs, we accept the child labour in (supplying) Asia?" "Eventually, you have a 50% change to belong to the (consolidated) big boys" "Parts of this scenario are already true, looking at international materials, productions and standard panels"

Circular Energy

	R&D	Warehouse	Installer's Project Developer
Support	Value in extra modular product design	Lots of executional tasks: sorting, logistics, maintenance	Executional experience helps qualitative reuse and transport services
Obstruct	No design optimisation and so increased cost prices	No distinctive products, minimal sales and high costs	High costs in quality, cleaning issues, more expensive for customer
Change	Need for inter sectorial collaboration and laws from governments	From supplier to service provider. Change of business.	Highly increased logistics and product handling

Table 11: Indicated supporting, obstructing and change factors for CE

Quotes

"The market will not collaborate to serve this collective system, because it pushes itself to have no margins". "It is a bit too unrealistically communistic". "This scenario needs an industry external push, as CO_2 pricing". "We are actually acting out elements as preferring a single mounting system for efficiency"

Scramble for Energy

	R&D	Warehouse	Installer's Project Developer
Support	Flexible portfolio changes, client mix, differentiation	Product differentiation, support in chaos; b2c market is margins	Easy to educate DIY product to installers, more consultation for clients
Obstruct	Chaotic offer changes, invest risks due to political changes.	Hard to assure quality, safety. Intense service with few resources.	Insane competition cuts margins, quality drop and DIY overtakes.
Change	Need for stable politics to preserve local industry	Rise of warranty, energy as service. Stability is USP.	Freelancers for B2C, cheap labour for B2B.

Table 12: Indicated supporting, obstructing and change factors for SfE

Quotes

"Segmenting on clients with a certain quality need means differentiation and margins". "It is developing towards this, all scrambling and diversifying products". "Individualism makes this scenario interesting". "Net congestion will occur because of individual optimising EMS".

Power to People

	R&D	Warehouse	Installer's Project Developer
Support	Product differentiation, additional benefits and clients	Product differentiation, consulting options with knowledge	More consulting, advising and analysing of (eco)energy-systems
Obstruct	More disproportionate norms, complexity and circumstances	Tenders means consolidation and project sales, no B2C	Intensive maintenance, biological restrictions and complexity
Change	Norms need to integrate and transcend sectors.	Integration of service to project sales. Norms on correct use.	Include biodiverse knowledge in install consultancy

Table 11: Indicated supporting, obstructing and change factors for PtP

Quotes

"Existing norms will not comply, so that will become difficult, and needs new alignment". "Tenders won't solely be about price, but about the best (ecological) solution; this creates more margin for us". "A potential mess of unknowledged consultancies". "Restrictions from nature are already relevant in certain projects".

In Table 12, we find that the support for scenario *Scramble for Energy* is strong and based on endless product differentiation and consultation of a chaotic client mix. What obstructs however, is the risks of quality and unstable market supply. The residential installer is potentially lost, as DIY products and human resource scarcity result into self instalment. What will change is how the product, instalment and energy security becomes fully individualistic, and will need policies to (minimally) protect workers, industry and equality. The quotes show a prospect towards individual energy scrambling.

For the scenario of *Power to People,* Table 13 shows similar strength in support by product differentiation and consultation, but now on biodiversity and societal advice. This scenario is obstructed by the complexity of these new multifunctional roof applications and accompanying collective project sales. What needs to change in order for this scenario to develop, is the norms and values on this integration of energy and nature, for building knowledge and collective project demand. The quotes show an understanding of norms, knowledge and practices to be developed.

10.3 Stakeholder Assessment Conclusion

By assessing the separate product scenarios with the stakeholders, I was able to not only get feedback on the scenario, but also find underlying values and interests of the stakeholders and the market they represent. In Figure 58, I present a final interpretation of these interests on the development of the key drivers. This leads to the following conclusions per scenario:

The ***Standardised Mass Energy*** scenario remains promising, but will fail without a drive for collective actions on energy and international sustainability. The stakeholders will only invest into this scenario when a single solar mounting product overrules all others in innovative quality, and a standardised install practice is inevitable.

The ***Circular Energy*** scenario is, in execution, too farfetched from a mass market, consumable and financial interest. Although justifiable, the scenario's focus on nature and climate is to strong for the consumer market. The stakeholders will not invest for this scenario, unless politics or economic systems change.

The ***Scramble for Energy*** scenario is the expected developing scenario for the visible future, for its energy security argument on individual sales levels. The stakeholders will invest in this scenario as long as margins are found in segmented market sales and product differentiation, until society/customers oppose inequality and push collective action.

At last, the ***Power to People*** scenario holds a promising realisable alternative, but is dependent on pacing knowledge development and societal paradigm changes. The stakeholders will invest in this scenario, when collective approaches for securing energy and nature emerge.

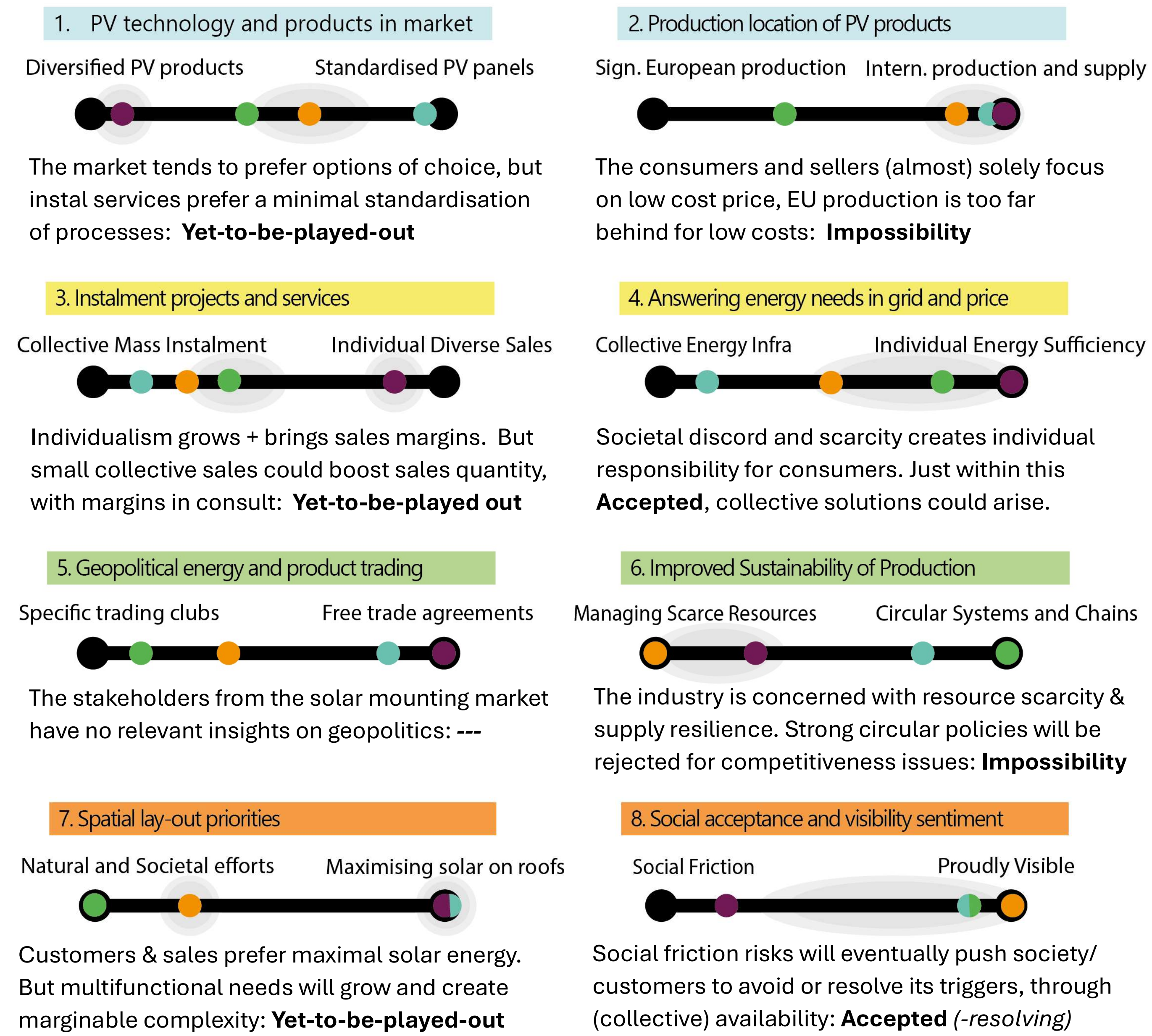


Figure 58: The stakeholders', so solar market's, interests reflected in the key drivers, revealing the yet-to-be-played-outs, accepteds and impossibilities of their development.

11. Future Vision

11.1 Future of the Industry

The insights from the stakeholder assessment on the product scenarios hint to a realistic, probable development for both of the Archipelagos scenarios. Of course all product-scenarios hold a certain amount of promising aspects for a realisable potential, which is supported by the trends and developments discovered in my industry analysis (Appendix B). Nevertheless, exactly this industry analysis, combined with geopolitical developments and solar market tendencies substantiates the general expected development of the solar industry towards a form of 'Scramble for Energy', certainly within the Archipelagos frame.

In Figure 59, I have drawn my interpretation of the solar industry's development, represented by those same four product-scenarios I constructed. In this projective representation, the four scenarios should not be seen as their fully developed 'end-states' that were constructed, but should rather be seen as directions of development, matching that scenario. In a certain timeframe in Figure 59, the relative share of a scenario-colour represents a similar share of market, product and (geo)political developments contributing to that scenario. In volume it also shows the unquestionable growth of the worldwide PV market.

In fast conclusion, the figure shows how all previous market developments have been pushing towards both the 'Standardised Mass Energy' direction as the 'Scramble for Energy' direction. But the latter is strongly becoming the dominant industry direction for the future, as growing individualism and geopolitical tensions make Archipelagos a reality. A side effect of this scenario-direction's growth is the potential emerging of the direction 'Power to People' as collectivised alternative and a small emerge of 'Circular Energy' movements as idealists' counter directions.

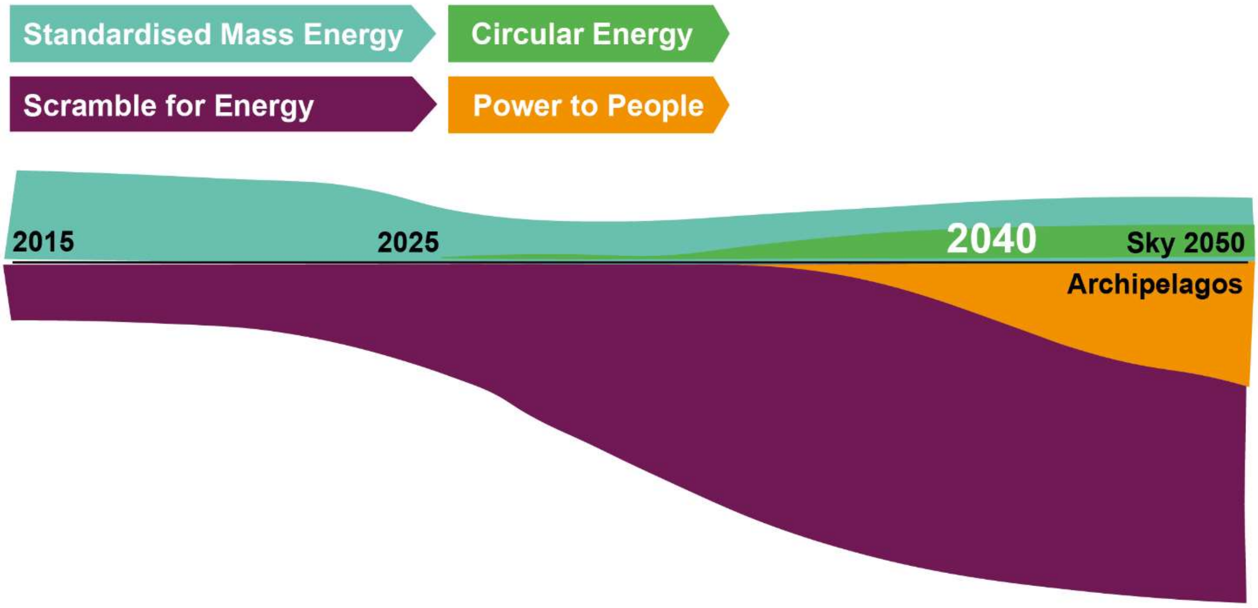


Figure 59: The for now most-likely expected development of the solar energy industry, represented by shares of development in directions of their resembling scenarios.

11.2 Future Vision

To create a strategy and roadmap for a company or industry group, it is helpful to develop a *Future Vision:* A vision that fits the companies attributes and qualities, and explains their view and role for the solar energy future.

A future Vision is allowed and helpful to be a bit provocative and challenging, but should be formulated within realisable futures too. Therefore, my future vision for Sunbeam and the mounting industry accepts the 'inevitable' Archipelagos, focuses on a greater push of the *Power to People* scenario, whilst preserving the good development aspects of the Sky 2050's scenarios for what is possible. This resulted in the following future vision:

Future Vision

Enable a climate neutral planned mounting of solar panels in joined and allocated projects, whilst improving local wealth, biodiversity and climate.

In this future vision, you will find elements from three scenario's, reflected by their corresponding colour. While the main focus is on promoting development of the 'Power to People' scenario, it lends qualities of standardised projects and climate neutral products from others.

According to the complex system change theory (Van der Bijl-Brouwer, 2024), strategic projects can act as market interventions to push the system to a preferred direction. As Sunbeam's desired direction is now the *Power to People* scenario, it can use product design to find collaborations, lobby for policies and offer user-value to push the market. The time-pacing strategy (Simonse, 2023) allows Sunbeam to also adapt for the emerging *Scramble for Energy* scenario and stabilise the business, whilst strategically plan for preferred developments. This should eventually lead to system change, as presented in Figure 60, attaining the Future Vision.

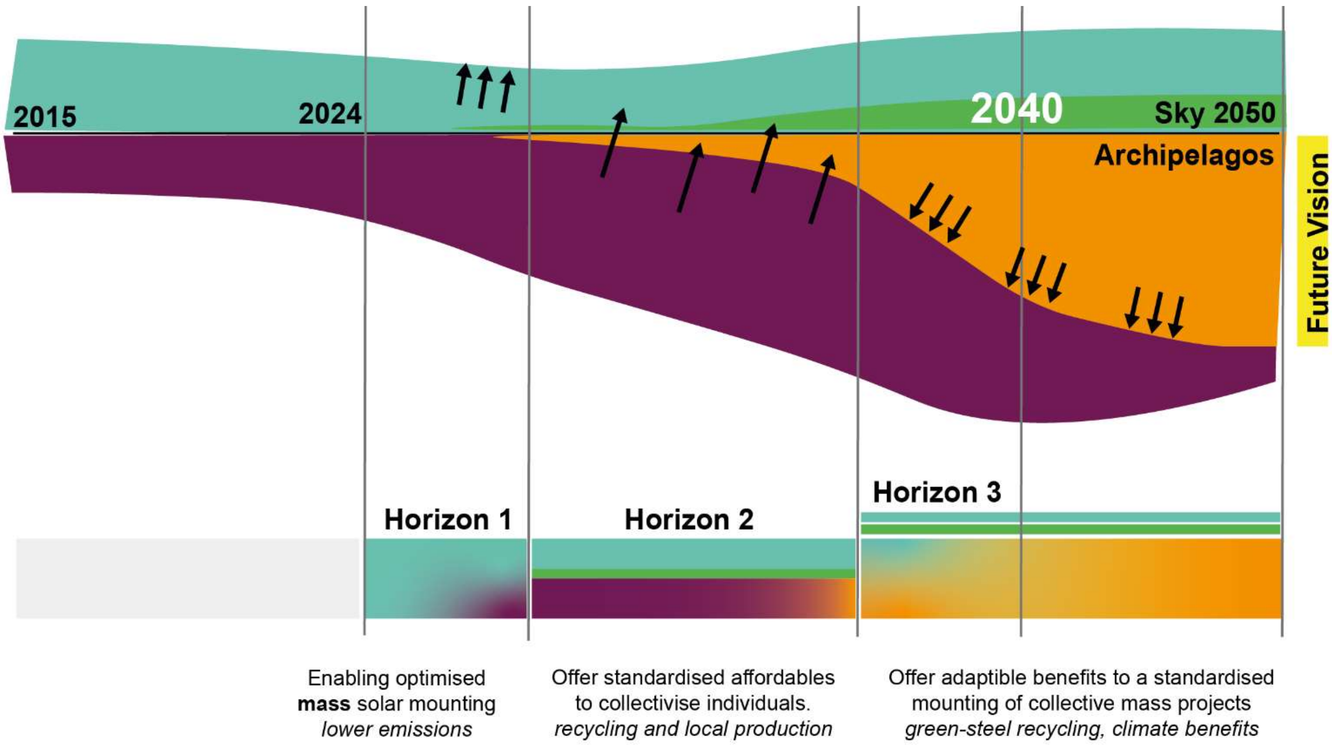


Figure 60: The three horizons and accommodating action that Sunbeam should strategise for, to attain the Future Vision by 2040

In Figure 61, the roll for Sunbeam in stabilising business and pushing development (black arrows) changes per horizon.
In Horizon 1, continuing from the present state, the company should actively steer away from the 'Scramble for Energy' scenario by boosting mass standardisation and optimising solar products for mass collective projects.
In the second stage, the company should offer valid alternative product designs that, although serving the 'Scramble for Energy' circumstances, proof and stimulate the development of the other preferred scenario directions. This is important to deflect the growth of the 'Scramble for Energy' scenario and to create support for alternative future directions.
In the third stage, the company should be an early provider of 'Power to People' inspired products and services, boosting the development of this scenario direction. They should now push these products and directions as superior and grow its share.

Figure 61 shows how the company Sunbeam's share in the market and product development looks:

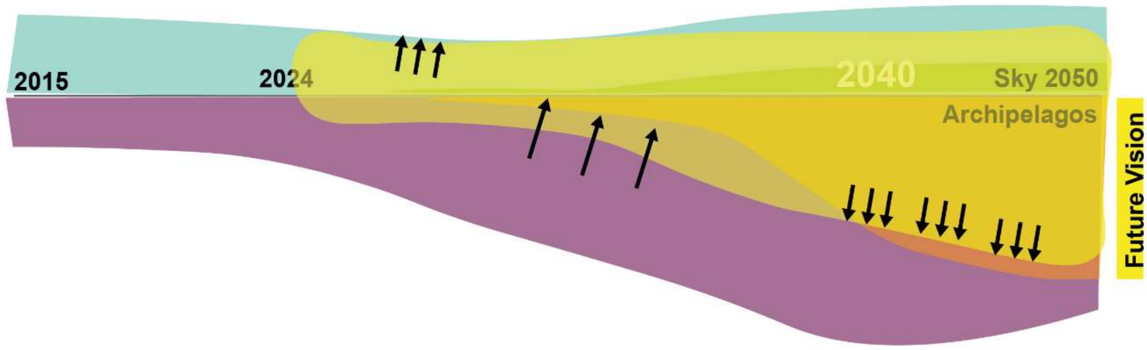


Figure 61: The envisioned market share of Sunbeam for solar mounting products, resembling both the share in direction developments and ambitious cumulative sales

In broader outlines, the presented future vision, system change efforts and corresponding horizons will be the basis for my constructed strategy and roadmaps for Sunbeam.

As phase: Future Visioning & Roadmapping — Develop the Logics

12. Roadmap

To develop a product- and business-strategy aiming for this Future Vision for Sunbeam, I created a strategic and tactical roadmap (Appendix Q). By creating an extensive overview of the estimated timing of industry developments, I could apply a time pacing strategy with the three horizons. While adapting to the emerging *Scramble for Energy* scenario, Sunbeam will strategically plan for a proposition fitting the 'Power to People' user and business values.

12.1 Horizon 1 (2028): Optimising solar mounting

Figure 62: Sunbeams products in horizon 1: a qualitative, optimised and fit-for-all product for install efficiency.

In the activities to horizon 1, Sunbeam will continue to strengthen its proposition in enabling optimised mass solar mounting, while further setting quality norms. As we near 2028, a growing competition on cost price, infrastructural limits and rising needs for renewable energy will push large energy users to efficient mass solar energy projects.

Products

Sunbeam's existing mounting systems Nova and Supra will enable efficient mounting. A strategic R&D project on biodiversity enhancing add-ons for Nova, will show Sunbeam's ambitions as Industry lead in sustainability.

Emissions

The cumulative emissions of Sunbeam's products will grow and keep being compensated. But efforts to buy low carbon steel in the supply chain stimulates collaborations for the future.

12.2 Horizon 2 (2036): Prefabricated panel batches

Figure 63: Sunbeam's products in horizon 2: Prefabrication of different sized solar panels, enabling cost-efficient installing and solar-panel batch sales for utility and large residential (groups).

In the activities to horizon 2, Sunbeam will have to adapt to the growing scramble for energy, resulting from energy shortages and instability. In the years approaching 2036, a growing international need for resource-, cost- and energy-efficiency forces the industry into protective contracts and collaborations to gain supply resilience. It is also creates value in recycling and local waste-based production.

Products
Sunbeam will position a new resource-efficient P90 product into the *Scramble for Energy* market. This mounting system fits the majority of roof use-cases and is prefabricated to batches of solar panels. It allows for fast instalment, pressing entry costs and enabling Energy as a Service business cases.

Emissions
As a P90 product reduces requirements in strength and adjustability, it could significantly reduce the amount of material needed in the design. With a growing sales quantity and the first disposed solar mounting systems becoming available for low-carbon recycling, cumulative emissions could gently start to stagnate.

12.3 Horizon 3 (2040): Planned added benefit projects

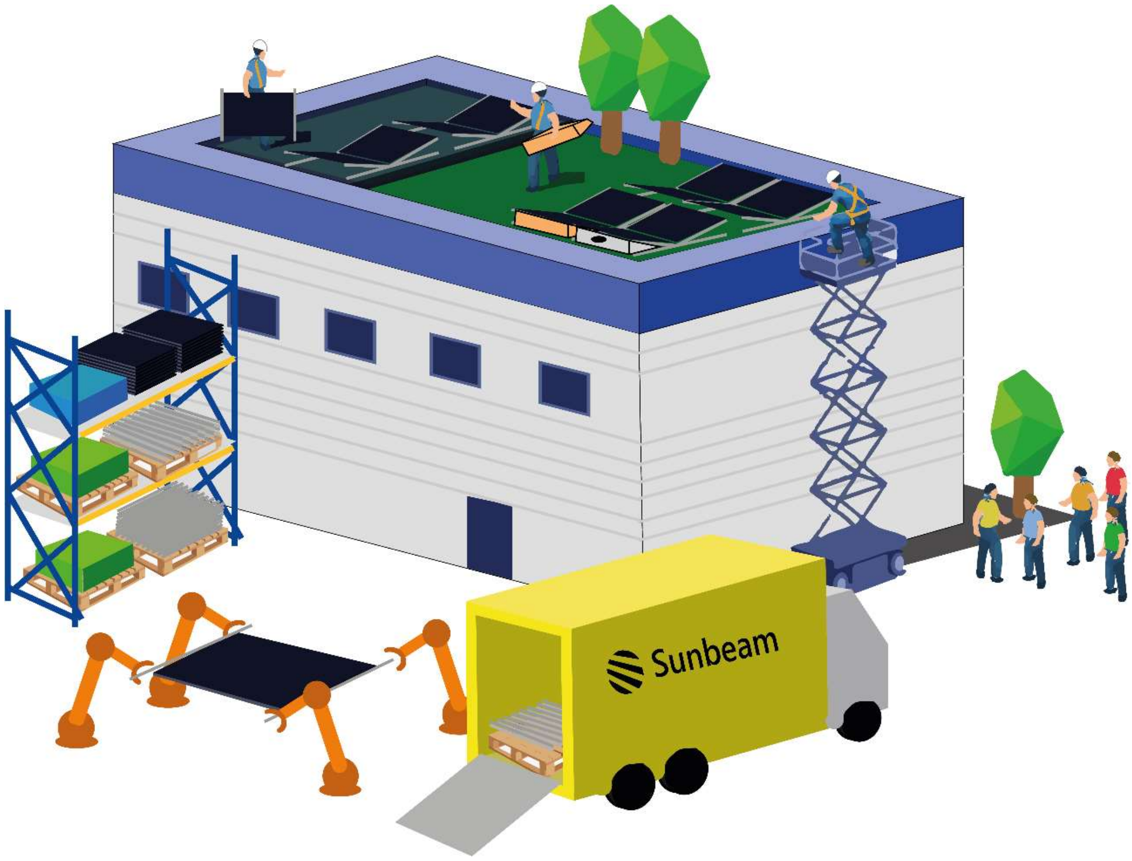


Figure 64: Sunbeam's products in horizon 3: preplanned mounting systems for solar panel batches in community-aimed tenders, offering adjustable beneficial products for biodiversity, water management and social wealth.

As we make our way to Horizon 3, Sunbeam should be able to observe a growing segment of society now realising how the effects of a *Scramble for Energy* scenario impact life. From somewhere around 2036, (inter)national tensions will have stimulated a movement for local wealth, energy equality and climate adaptation. Just as companies find their own way to energy stability, communities and governments will plan for collective energy hubs.

Products

Sunbeam will be an early provider of standard customisable sets of mounting products, that can be matched and adjusted to serve new value propositions in local added benefits. On demand of community and government clients, project developers consult and plan mounting-projects that benefit local biodiversity, employment and water management.

Emissions

As the product portfolio starts to include more and more product add-ons, Sunbeam grows beyond just steel products, and creates a more resilient material mix. By a combination of recycling efforts and green steel purchases, and the internal product compensation of add-ons made from wood, waste or carbon capturing materials, Sunbeam has a change to finally decrease and possibly neutralise emissions from its products.

13. Discussion

The goal of this master thesis was the 'Design of future product-scenarios for a climate neutral solar-mounting system on flat roofs in 2040'. Through an adjusted approach on industry scenario construction, four product scenarios were successfully developed: Standardized Mass Energy (SME), Circular Energy (CE), Scramble for Energy (SfE), and Power to People (PtP). By applying an iterative design approach, I aimed to research how different product-scenarios could shape the development and sustainability of solar mounting products, with a particular focus on achieving climate neutrality by 2040. My findings in roadmap development and stakeholder assessment demonstrate that all scenarios offer a realisable prospect for the industry and create a variable perspective to inspire discussion, envisioning and strategy building.

Limitations

The application of Shell's Energy Security scenarios provided a valuable framework for exploring potential industry end-states. But, there are justifiable concerns for the use of scenarios developed by an oil company, specifically such as Shell, known for its unwarranted interference and disruption of independent climate change research and communications (Waldman, 2024). However, scenarios can never be seen as verifiable predictions of the future, but are provocative perspectives for an industry. And the Shell's scenarios for the energy industry aligned within all (remotely) possible industry developments of key drivers I found in my research, making them a useful tool for scenario construction. The successful use of the resulting product scenarios in my stakeholder assessment also confirmed the credibility of the resulted perspectives.

This research also highlights the difficulty of achieving climate-neutral solar mounting products. As for a climate neutral product, the challenge mainly lies in the materials and the production processes, which are heavily dependent on advancements of production industries as green steel or biobased production. From my design research, I can only conclude that climate-neutral products could be more likely in some scenarios, depending the required product portfolio and broader changes in the industry.

For both the SME as the CE scenario, a climate neutral product could be made from 100% recycled green-hydrogen steel, as, in those scenarios, the capacity of renewable energy might be increased substantially by 2040. For the PtP scenario, it might be made of recycled grey-energy steel, and compensated by internal wooden/waste-based/carbon capturing products or ballast.

Eventually, my scenario construction further highlighted the importance of the prior sustainable objective: to enable a sustainable handling of solar products. In researching the development of key drivers in the mounting industry, I can only reinforce the serving characteristic of the mounting industry, subject to the (sustainable-)development of solar energy consumer and business needs.

Hypothesis

In my hypothesis, I suggested that 'scenarios and product designs can mutually reinforce each other's success and realisation'. I explained how a product scenario could become a successful intervention to change strategies and stimulate development towards desired developments, both for the constructing company as the stakeholders.

Unfortunately, the stakeholder assessment did not directly measure the impact of product scenarios on stakeholders, which limits how well I can confirm the hypothesis. But the developed Future Vision and roadmaps fur Sunbeam show the potential value of combining scenario construction with product design, resulting in a practical approach to strategic planning in product development.

Continuation of scenarios

The nature of scenario-based research means the constructed mixes and perspectives of my constructed scenarios are influenced by timing, selectively discovered trends, and available knowledge at the time they are constructed, and could (or probably should) change as new information emerges. It is therefore important to regularly revisit the product-scenario design process to reconstruct scenarios and potentially revisit roadmaps and strategies.

Additionally, it's important to keep monitoring the pace of industry trends and technological advancements to make sure that the strategic planning within a roadmap stays up to date with the latest developments.

Recommendations

Future research should consider including alternative end-states beyond the Shell scenarios, to reduce potential biases and offer a more varied view of industry futures. More efforts in tracking the development and scaling of low-carbon and green steel technologies is also recommended, as this will be an important factor for planning the climate-neutral aspect of solar mounting products. Additionally, future studies could directly assess how product scenarios could impact stakeholder decision-making to confirm the hypothesis more clearly. If successful, the product scenarios could be deployed as interventions to stimulate developments and collaborations in the industry, stimulating the realisation of desired directions.

14. Conclusion

This thesis has explored the potential future direction of the solar mounting industry, by developing and analysing four product scenarios: Standardized Mass Energy, Circular Energy, Scramble for Energy, and Power to People. Developed through an a iterative design approach, each product and scenario successfully projects a potential path of development for the industry, while uncovering clear differences in attitude towards (international) collaborations and sustainability efforts.

The Standardized Mass Energy scenario shows promise due to its focus on large-scale, standardised installation efforts that can drive down costs and boost renewable energy capacity. However, its success is heavily reliant on collective actions and international collaboration, for policies ensuring sustainability and investments in energy infrastructure. Without these, the market will fail to standardise from lack of necessity.

The Circular Energy scenario, although idealistic (and realistic) in the actual needs for sustainability and circularity, faces significant challenges in terms of market acceptance and financial viability. Setting up a future of reuse-systems and a nature-inclusive use of space is prestigious, but it remains too far removed from current market demands. This makes actual realisation unlikely, unless there are substantial shifts in political and economic views.

The Scramble for Energy scenario appears to be the most likely near-term development. Its cost pressed offer of varying solar and mounting products answers to the growing demand for individual energy security. Scarcity results in segmented markets, leading to chaotic product differentiation in price and sales margins. However, this scenario may lead to increased energy inequality and instability, as it builds on individual rather than collective solutions.

At last, the Power to People scenario is the most desirable but also transformative from a solar mounting industry perspective. Its mounting products with additional focus on local nature, climate adaptation and social wealth demand significant restructuring of industry services. The complex knowledge and new collaborations required are achievable, but will need a change in norms and policies on energy equality and collective solutions.

In conclusion, while the Scramble for Energy scenario may dominate in the near future, as it best aligns with current market forces, the Power to People scenario offers the most promising alternative. Industry development towards this desired direction could be realised, if stakeholders can mobilise the necessary resources and societal support through strong product interventions.

In following and adjusting a constructed roadmap, the solar mounting company Sunbeam should strategically balance immediate market needs with long-term sustainability goals, by integrating (product-)elements from multiple scenarios. Taking an active role as industry leader, Sunbeam should work on collaborations and project developments that can intervene and inspire the market and society. By these efforts, Sunbeam will have a chance to create a future solar mounting context or client segment for which the ambitioned ‘climate neutral solar mounting product’ can be developed.

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Appendix A: List of Minimal Requirements

In excel file 'List of Minimal Requirements Solar Mounting Product Scenarios - 2024 - TU Delft IPD' you can find the list of minimal requirements.

Minimal requirements list

Circular Energy

Standardised Mass Solar

Scramble for Energy util.

Scramble for Energy res.

Power to People

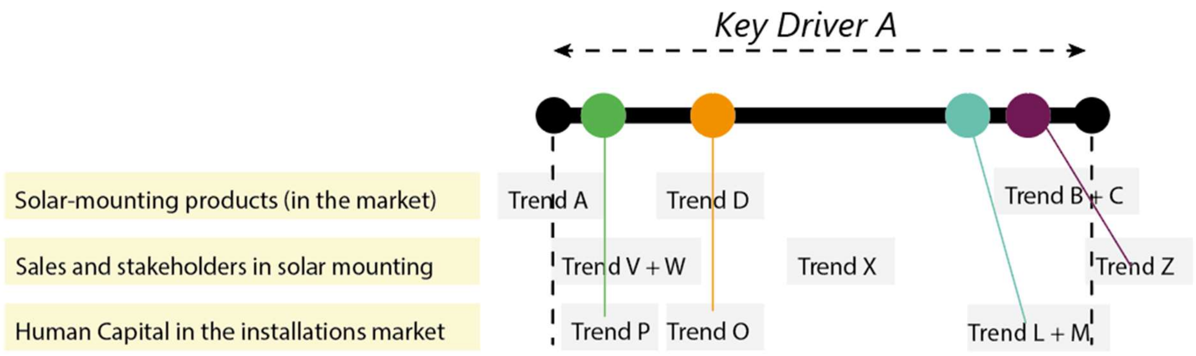
It also shows a List of Future Requirements per Product-Scenario. For the Scramble for Energy scenario, I created a separate list of requirement per utility and residential category, as in this scenario those use-cases can differ significantly due to the chaotic market.

Appendix B: Solar Industry Trend analysis

In the figure on the next page, you can find all the industry subjects that I studied in my trends & development analysis of the Solar Mounting Industry. The different subjects cover all levels of the solar mounting industry: micro, meso and macro levels. Within each topic, I have listed what factors I studied on.

The figure below explains how this trend & development analysis has lead to the identification of the eight key drivers. I clustered trends from one or many researched subjects, hinting or pushing contradicting outcomes of an undefined development. By finding the overarching subject of these opposing trends, I was able to identify the key driver.

Although not planned to be, this process was intuitively inspired by the ViP-Method's (Hekkert et al., 2011) steps of generating context factors, and structuring the context. Similar to their method, I found context factors on the subject of solar mounting and structured them into dimensions of potential development. These dimensions became my key drivers.



In eventually constructing the scenarios, I searched for matching potential key driver development outcomes throughout all the key drivers, building to an inspiring but realistic scenario.
So, contrary to the ViP method, I did not create my own designer-statement to help the design of an envisioned future product. Instead, I created substantiated industry-directions, that set up discussable perspectives in every direction. Simply said, I did not choose a certain vision, but for visions in all directions.

The trends and developments that I found in my research are presented in Appendix M, by the scenario they fit. So all trends are used as substantiation for development outcome of a driver that they best support. As visualised in the figure above.

Trends & Development analysis:	Scale	
Solar mounting product perception	Products	Micro
Perception of sustainability in products		
Household barriers for environmental friendly technologies		
The opinion of society on different renewable energy forms and locations		
Solar-mounting products (in the market)	Products	
Solar Mounting Minimal Program of Requirements		
Competitive Market Analysis		
Solar Solutions Fair visit, search for USP's on solar mounting products		
Sales and stakeholders in solar mounting	Industry	Meso
Stakeholder interviews		
Solar Solutions Fair search for collaborative and competitive opinions		
Sunbeam internal observations on Sales processes		
Costs of structure, personel and instal efficiency innovations		
Human Capital in the installations market	Industry	
Stakeholder interviews		
European and National reports on human technical resources		
Costs of structure, personel and instal efficiency innovations		
Feasibility of Dutch roofs for solar mounting	Industry	
Feasibility reports of Dutch roofs		
Available budgets and subsidies for improvement of building structures		
Alternative spatial allocations for roofs in the Netherlands		
PV production and technology	Industry	
Interview with dutch scientist and PV expert		
Scientific papers on sustainability, performance, growth of new technologies		
Reports on international PV production, locations industry growth		
Research on alternative PV products, and product mounting		
National/EU solar capacity ambitions	Energy	Macro
Renewable energy needs and ambitioned installed solar capacity reports		
Policies on stimulating renewable energy, eg EU Green Deal, Klimaatakkoord		
(Shell Energy Security scenarios)		
Sustainable Materials & Production	Energy	
Sustainable improvement paths of steel/aluminium by green hydrogen		
(Scientific) development of alternative biobased / recyclables / composites		
Development of Technological Industry & Energy in sustainability		
International climate policies & economics	Energy	
Policies on European ESG costs and carbon pricing		
Policies on European customer protection and sustainability claims		
Geopolitical research on climate ambitions and accords		

Appendix C: PV Technology

In this Appendix, I will summarise my research on the future of PV technology. As the variety of technologies show potential development into several circular, structural or performance directions, the outcome for the PV technology an so the required solar mounting is depended.

5.1.1 Crystalline silicon (cSi)

By far the most common PV technology in production is that of crystalline silicon (cSi). The technology internationally holds for 95% of all PV production (Fraunhofer ISE, 2023), with around 85% for mono-crystalline technology. Other technologies are poly/PERC/IBC/half-cells and more.

Structural details
The standard cSi PV-panels are rigid rectangular panels. Sizes of panels have been growing, due to increased cell covering. The most common distances are given by TNO (2023):

	WIDTH			LENGTH		
	number of cells	basic size [mm]	maximum size [mm]	number of cells	basic size [mm]	maximum size [mm]
size 1	6	994	1322	12	1984	2000
size 2	8	1323	1500	12	1984	2000
size 3	6	994	1322	8	1343	1662
size 4	6	944	1322	10	1663	1983

Figure XX: cSi panel dimensions (TNO, 2023)

Efficiency and Performance
Marketed PV-modules perform with an energy conversion up to 21% (TNO, 2023), and generally 17-18% for mono crystalline (ElKhamisy et al., 2023). The heat-drop of performance is 10-15%. The expected lifetime of cSi panels is 20-25 years (Weeber, 2024). An increasing percentage of the cSi market is becoming bifacial, as efficiency of a panel improves from reflecting indirect sunlight to the backside.

Sustainability & potential (TNO, 2023)
The main climate change impact in a PV-panel comes from silicon cell (60-81%), the glass plates (6-14%) and the aluminium frame (9%). The cSi technology uses around three times the amount of minerals and metal as CIGS. The technology holds the potential to be up to 90% recyclable, although with high efforts.

Applications and development
Mainly applied in rigid PV Panels. Strong development and availability of coloured panels (lower performance). Also applied as (mini) single solar cells in products and BIPV.

5.1.2 Thin Film (mostly CIGS)

The other certainly relevant PV-technology is that of the **thin-film** PV-cell. It is based either on Cd, amorphous-Silicon (a-Si) or CIGS (TNO, 2023). Besides the smaller market size, thin-film production is expected to grow with a rate of 12.1% per year (Research And Markets Ltd, n.d.).

Structural details (TNO, 2023)
These PV-modules are normally flexible. Any flexible substrate enables up to a 4,5 cm bending radius, with a width from 20 up to 2000 mm, and a length of 150mm up to 10 meters. They weigh around 2,5 – 1 kg per m2. According to TNO, the cSi and CIGS technology clearly distinct between rigid and flexible:

		PV Technology	
		cSi	CIGS
Form	rigid	>95%	rare
	flexible	rare	>95%

Figure XX: flexible and rigid PV differentiation (TNO, 2023)

Efficiency and Performance
The performance of thin film solar cells now goes up to a power conversion of 17%, but generally 10-15% (ElKhamisy et al., 2023). The PV panels hold a shorter expected lifespan of around 10 years (Weeber, 2024). Innovation in thin-film technology has shown potentials up to a performance of 33% (ElKhamisy et al., 2023).

Sustainability and potential
As the market is smaller, there are even less recycling facilities set up for thin-film PV. The required amount of energy for production is quit lower than cSi, and uses a third of the minerals and metals. Attempts to production from organic materials, an environmental friendly thin-film cell (so no module) led to a lab performance of 15,2 % (ETIP et al., 2021).

Application and development
Thin-film PV is mostly applied by permanent fixation onto organically formed structures, vehicles etc. Another application that can be found is PV on a roll, to stick on surfaces as facades and sometimes roofs. However, large scale application is currently limited, due to low production volume and lower performance than cSi (ETIP et al., 2021).

5.1.3 Perovskite

According to ETIP et al. (2021), Europe is the leader of perovskite-PV as the most promising emerging PV technology (as well as Tandem approaches).

Structural details
This technology can be applied on flexible and semi-transparant substrates, as well as rigid (ETIP et al., 2021).

Efficiency and Performance
For this new innovated technology, a produced mini-module has delivered a performance of 17.9% (ETIP et al., 2021). The maximum proven efficiency for a cell is 25.8%. (TNO, 2023)

Sustainability and potential
Perovskite would use no critical materials and a lower energy consumption in production. The technology holds ‘potential to low-cost and high-speed production methods’ (ETIP et al., 2021), but questions remain about reliability.

Application and development
Applications are limited. But perovskite is mostly mentioned as a possibility to apply in tandem solutions with cSi or CIGS. For example, a cSi+perovskite module has performed around 27% .

5.1.4 Tandem

Efficiency and Performance + Sustainable Potential
The relatively young tandem technology combines layers of different PV technologies to achieve higher efficiency rates. Europe has a high level of expertise on this emerging technology. ‘A threshold of 20% efficiency for the tandem PV modules is anticipated’, and is named as

beneficial for European production as technology ‘vital for the world for ecological and competitiveness-related reasons’ (ETIP et al., 2021).

Application and development
For such an emerging technology, it is hard to predict growth, but ETIP et al. expect a growth to a market share of more then 5% in 2030 as mass market application.

5.1.4 Bifacial

Efficiency and Performance
The technology of bifacial panels focuses on creating PV panels that also capture light from the back of the panel. This can increase the electricity yield by about 10 to 20% (Bifacial Solar Panels | TNO, n.d.). So concluding to cell efficiencies of over 23%.

Application and development
In reducing the amount of PV panels. Or in vertical solar or tracking systems, opening room for irradiation between and under panels as well, interesting for green-roofs and agriculture (Bifacial Solar Panels | TNO, n.d.).

Appendix D: PV Production and Ambitions

European Union Ambitions

The EU Solar Energy strategy tells us that the EU suggests to aim for an installed solar capacity of 320GW by 2025, and 600GW by 2030. That is, on average, approximately 45 GW installed capacity per year (European Commission, 2022). Roughly resulting into yearly energy production of something around 1.500 TWh.

This stands in small contrast to the projected global need for solar energy of around 93.000 TWh when ambitioning climate neutrality in 2050 (LUT University et al., 2019).

The EU Solar Energy strategy describes several relevant actions to reach their ambitions (European Commission, 2022):

- Ensure that all new buildings are solar ready.
- Obligate the installation of solar on commercial buildings of >250m2 by 2027.
- Make solar compulsory for al newly build residential buildings from 2029.

Dutch Ambitions

The Dutch target for renewable energy in 2030 has been updated in 2021, and aims for an renewable energy production of 200 TWh/year, of which a significant amount still as undetermined type of supply:

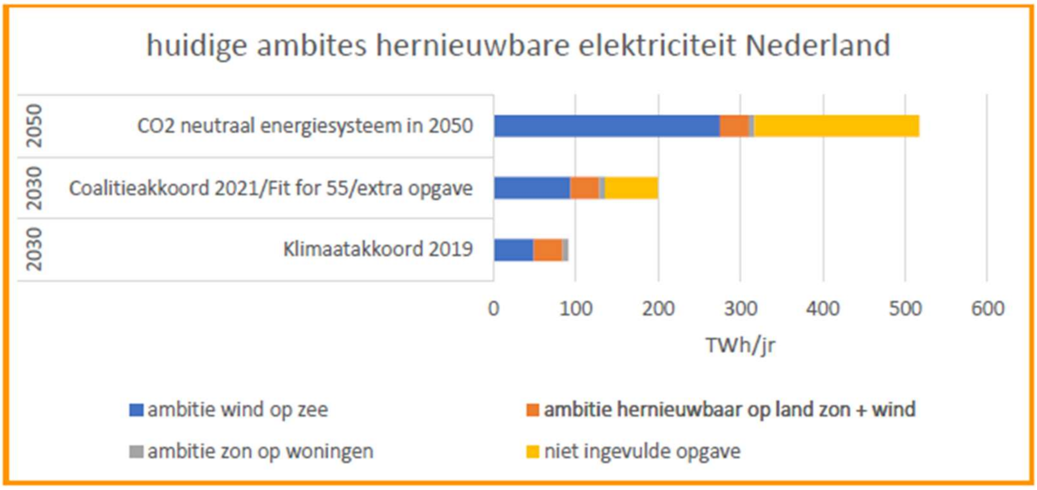


Figure XX: Renewable energy ambitions Netherlands (TKI Urban Energy, 2022)

The solar ambition aim for an installed capacity for solar energy in 2030 is 26 GWp, with a yearly result of 23 TWh (TKI Urban Energy et al., 2021). In this goal, the Dutch government aims for 7 TWh/y on residential buildings, commercially established, and the remaining TWh/y resulting from utility and land projects.

From all ambitions, it may be clear that there is a strong growing demand for PV capacity, envisioned as only exponentially growing after the concretised numbers for 2030.

Production and location

According to Sinke (2023), the last decade, the exponential growth of PV production has only ever been underestimated. The market share in production by China has grown tremendously, just as its production capacity. The figure below clearly shows how the worldly demand for PV production is depended from the Chinese production.

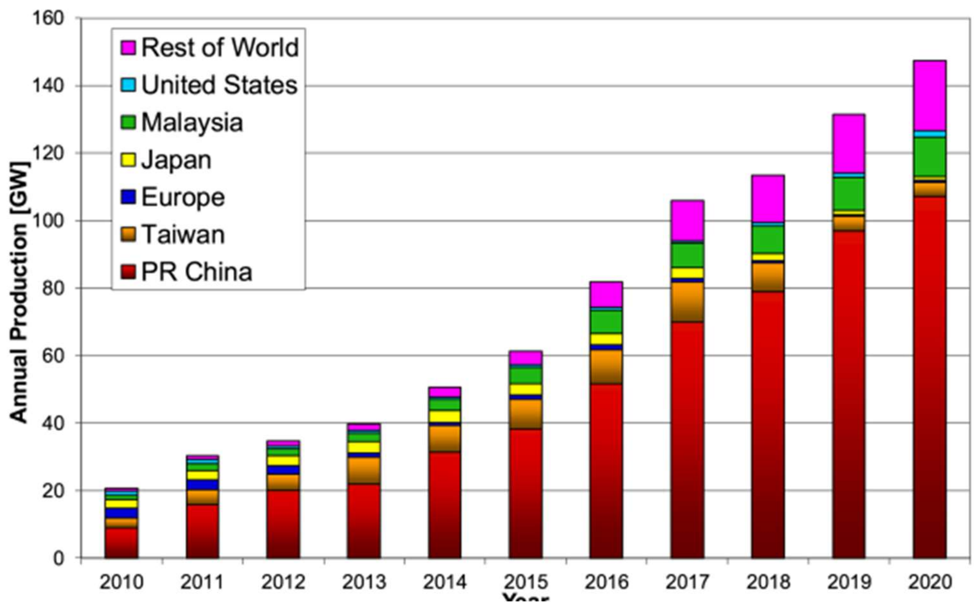


Figure XX: World PV cell/thin film module production from 2010 to 2020 (Jäger-Waldau, 2021).

Even more, in a report of Fraunhofer ISE (2023), we can see that for the production of PV in Europe, we are still mainly depended from cell and wafer production from outside of the EU. The majority of production of PV in the EU takes part in the production of the module, and the production material Silicon. The essential production step of wafer production and cell creation is very limited, and mainly outsourced.

The EU has not succeeded yet in keeping an European production stimulus (Appendix E).

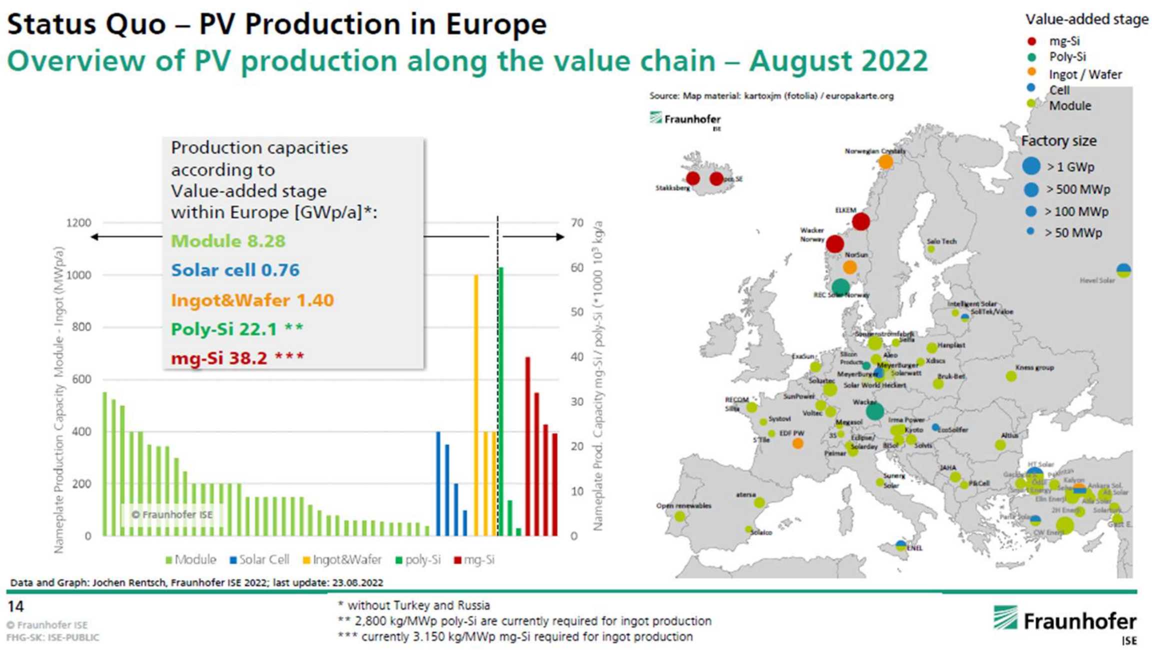


Figure XX: Status Quo – PV Production in Europe, august 2022 (Fraunhofer ISE, 2023)

Appendix E: Sales Stakeholders

The installation sector for solar panels in the Netherlands is growing with the ever-going increase of solar-panel placement on buildings. In this chapter, I will discuss the type of stakeholders, their (change in) role in value-flow and logistics, and the stakes and goals that drive them. These conclusions are based on insights generated from a visit to the Solar Solutions Fair, desktop research an interviews with stakeholders (Appendix K)

I will start with a list of the stakeholders in the installation-sector and construct a stable definition to a certain stakeholder-role, as they tend to overlap and change in other aspects. The trends and developments found per stakeholder are also noted.

PV supply outside-EU / China
Definition: Producer/supplier market of PV-panels from outside of the EU, mostly from China.
Present and past: Via early subsidies and an export-oriented envisioning (Nahm, 2023), the PV-supply is nowadays strongly dependent from China.
Product development: For years, the commonly available produced PV-panels are growing in size, as this would benefit the cost-capacity ratio for production per panel. In the EU, only the German (Appendix K) policies on dimensioning might have created a managed demand for smaller panels. In all other, the dimensions are simply supply-driven, from China.
Market development: There is no reason to believe the PV market supply will not continue to grow and expand export numbers to the EU.

PV supply EU
Definition: Supplier of PV-panels with cell-production and assembling located within the EU.
Present and past: There are a few companies with production of PV within the EU. Companies can struggle with sustained losses, as the producer MeyerBurger (2024) states “due to a lack of European protection against unfair competition from China”.
Product development: These local companies try to differentiate on circularity/sustainability of the product, customised panel-dimensions or new solar technologies for BIPV.
Market development: As example, the company MeyerBurger (2024) is relocating (parts of) production to the US, where the market is now more attractive for solar production.

Solar Mounting supply
Definition: Producer and supplier of solar-mounting solutions for PV-panels.
Present and past: The solar mounting industry within the Netherlands has increased simultaneously with the demand of solar panels. The demand for mounting solutions within the EU is generally fulfilled by EU production companies, located in the Benelux.
Product development: Products for the more general roofs in the EU are in market. Development is in increasing installers-comfort and product-sustainability, and adapting to new solar-panels. And there are producers expanding to carports and other solar-markets as land, BIPV etc.
Market development: Producers are in a lateral growth of sales, but dependent from the solar-market in residential and utility. Producers are also focussing on market expansion outside the Benelux.

Warehouse
Definition: Sales and logistics institute responsible for bringing together panels, mounting and tools for installers.
Service Development: With only taking care of logistics, a warehouse is no longer adding enough value (Appendix K) Although these companies hold the main grip on logistics, they are in a

struggle of finding more service to offer, such as:
- Expanding the logistics and handling section, expanding B2C: delivering pre-sorted or even prefabbed (by the whole-saler) packages and installation tools for extreme installers efficiency, and taking back (reusable) packaging and cleaning up.
- Adding service and consult: taking in the role of energy-consultant and become the point of contact for adding products, configurating energy-systems and matching installers with the client.

Market Development: There are enough warehouses to meet the market, so now bigger companies are taking over smaller ones. They are also aiming for chain-integration, so taking over chain-elements from even supply (self-production) up to acquisition of installers.

Installer Groups
Definition: A company that is planning, delivering and installing solar panels, coordinated with the customer. Mostly residential and small businesses as clients.
Service Development: From installing, they are growing into the role of energy-consultant, advising and offering additional energy-management products.
Market Development: Installers shortage, which results in non-capable installers and lack of certification drive. No policies on certification of installers are in sight.

Installer Individual (ZZP)
Definition: A freelancer that is installing solar panels on buildings, and potentially takes care of delivering and/or planning&coordinating.
Service Development: Growing dimensions of solar panels and accompanying safety and misfit issues, leading to mounting-system preferences.
Market Development: Forced by market competition to specialise and increase efficiency, and therefore outsourcing tasks and/or using supportive tools from partners.

Project Developer
Definition: A company that takes responsibility for establishing, coordinating, planning and the delivering and installing of solar panel (fields) for bigger business solar projects. Potentially also the service/maintenance.
Service Development: Full involvement in structural study of the buildings allowance and match with solar-mounting. Handling service and guarantee mediation. Increased reporting and consulting on ESG, repowering and energy management.
Market Development: Increasing solar projects, expanding to markets as carports, or land and water.

Service/Maintenance Providers
Definition: A company providing the service and maintenance activities for solar-panel owners. Can be for residential or for utility clients.
Service Development: This service is more and more specialised, so that it is no longer combined with installing or energy-management activities.
Market Development: Increasing market, being outsourced from installers. But again, being implemented by warehouse or project developers.

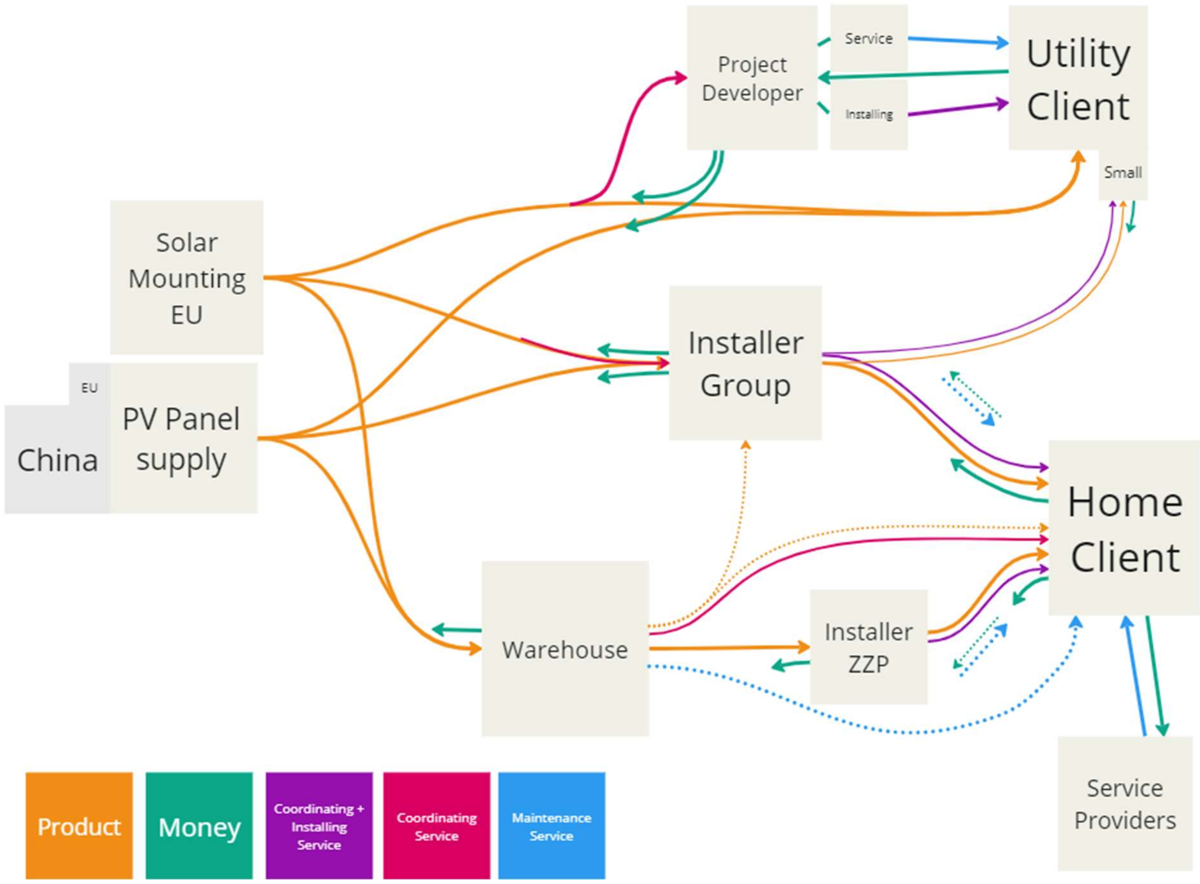
Residential Client
Definition: Customer of solar-panel installation from the residential, private market
Needs: Consultation and installation of products for best match in investment payback-time, energy usage, roof area and personal values
Values: Safety (house), Safety installer, Sustainable Energy, Circulair products, Service, Liability,

Financial certainty

Utility Client
Definition: Customer of solar-panel installation project for utility buildings, from the public or business market.
Needs: Consultation and installation of solar & management-system for maximal green energy usage and return of investment (+subsidy and project management)
Values: Green image, ESG's, electrification

Sales & Logistics Process

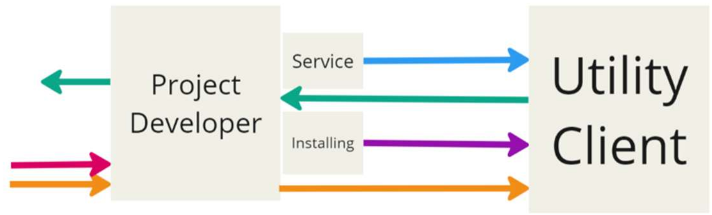
With all these stakeholder types on play in the solar installation market, it is important to understand the current value transactions and trends changing them. In figure XX, the present value transactions are shown with arrows representing product, money, coordinating-service (+installing) and maintenance-service.



As can be seen, the value transactions are very complex for the amount of stakeholders that are in the market. This is due to the fact that for the eventual sales between panel+mounting supply and installing at the client, almost all accompanying tasks (logistics, coordination, service, installing) can be claimed by any of the stakeholders. Although they all originate from an expertise task, they try to expand their business by offering the tasks originally hold by others.

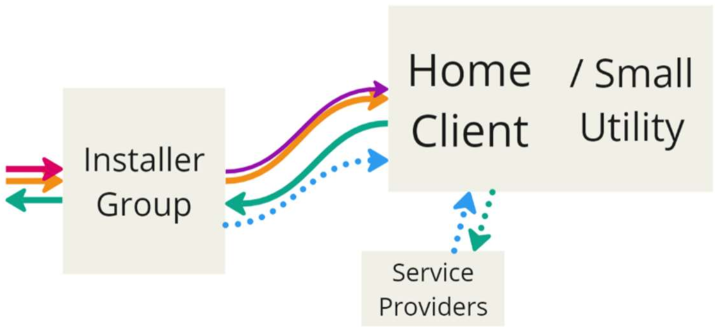
But, the most common value transactions are still best explained per project developer (1), installer group (2) and warehouse-installer (3) cases.

Project Developer



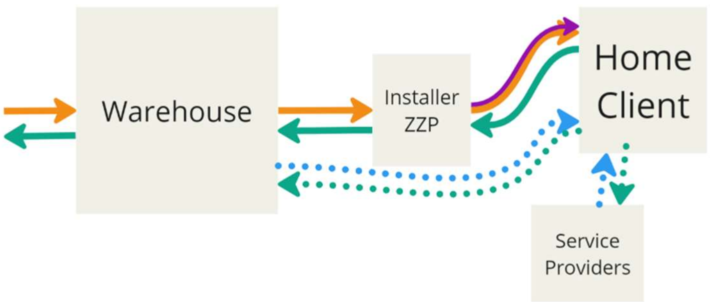
The majority of Project developers focus on consulting and facilitating the installation of larger solar fields on utility(-size) buildings. They arrange their own solar and mounting storage and provide installers. As fields are big and maintenance and service is project base, they have their own service employees.

Installer Group



An installer group typically executes the same kind of actions as a project developer, but then for residential clients or small utility projects. Because of the large amount of clients and small fields, service is outsourced to private service contracts.

Warehouse + Installer (ZZP)



Another option in the residential market is the installation by freelancers, sometimes combined with other installation practices. Products are stored in warehouses and picked-up or home-delivered per project. Service contracts are sometimes outsourced, but reliability on the original installer is still existent.

Appendix F: Instal and Service costs

The installation of solar panels in the Netherlands has been growing yearly, as the customer market for solar energy became more attractive through cost reduction and stimulating policies.

PV and installation costs

The typical costs for PV panels (type cSi) have been decreasing over the last years, and are expected to keep decreasing in the coming years. Also, the total costs for installing and electric system has been decreasing mostly and are expected to stabilise (RVO et al., 2023).

Jaar	Woning – 10 KWp	Bedrijfsdak 100-250 kWp	Groot bedrijfs-dak > 1 tot 10 MWp	Veld-systeem 10-20 MWp	Veld-systeem >20MWp
Referentie	*3 kWp*	*250 kWp*	*2,5 MWp*	*10 MWp*	*30 MWp*
Typische toepassing	*Dak op woning*	*Dak bedrijf, mkb, agro, publiek gebouw*	*Dak bedrijf, industrie, distributie-centra*	*Grond-gebonden*	*Grond-gebonden*
2019	1,31	0,98	0,871		
2020	1,26	0,77			
2021	1,20	0,70	0,75		
2022	1,83	0,59	0,68	0,74	
	Verwachte prijsontwikkeling (vlg eindadvies SDE)				
2023		0,60	0,57	0,64	
2024		0,63	0,56	0,54	
2025			0,55	0,48	0,46
2026				0,49	0,46

Figure 1: National trends for system prices of different applications in €/Wp (RVO et al., 2023)

To further understand how these costs are established, MIT et al. (2015) made an overview of the costs share of module, hardware, engineering and more per PV system type:

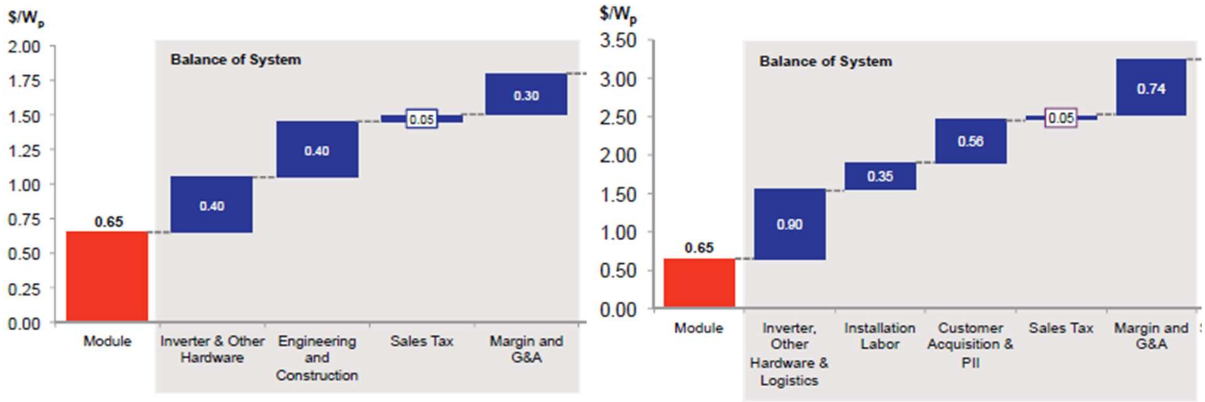


Figure 2: Stair step build-up of estimated costs for utility (left) and residential (right), (MIT et al., 2015)

Although all these costs have decreased since 2015, the mutual shares of all balance of systems costs have roughly staid the same. The cost share of the module has significantly dropped. Therefore, the relative share of BoS has risen, and influences the payback time even more.

Weeber (2024) (Appendix J) states that this drives the demand for even more efficient panels, as to increase power capacity per installation. It is also a driving factor for more pre-fabricated install solutions as BIPV installations. Due to this cost-share, the solar mounting is mainly a cost-price driven market.

Grid congestion and self sufficiency

Besides the prices of PV and solar mounting, other factors that influence the needs of customers is the grid connection and energy pricing. The availability and prices for producing solar energy back to the grid influences the installed solar capacity (Rijksoverheid, 2022). To become so called 'prosumers' boosts the amount of renewable energy in the energy infrastructure. So one focus of the government and industry could be on improving the grid up to the maximal necessary capacity, so that all users install the maximal solar panels and produce for the grid.

But, high customer prices and dynamic or stable pricing for buying energy from the grid can also push a utility or residential user for boosting self sufficient solar capacity. By applying energy management systems or batteries to optimally use their solar energy, or by implementing energy conservation measures, customers can choose for a more self sufficient approach. And as the grid is limited, all connections could be re-evaluated for importance (Acm, 2024).

Appendix G: Sustainable Productions

Within my iterative design research and development of products for the scenarios, I did research in the climate neutral potential of green steel, bio materials, carbon capturing and into the sustainable strategies of circular economy principles.

Waste based and Bio materials as compensation
As the inclusion of biomaterials could enhance negative carbon numbers, reinforced compositions and wood (Titirici et al., 2022) could be strategized for as internal compensating materials and processes. Current examples of such products, as Resysta's biowaste 'timber' (Gadero, n.d.) and biocomposites from Tipwood (bioframe.com, n.d.), show potential in similar applications. The Dutch company NPSP also creates steel competitive composites that are biobased or waste based, potentially using local supply of resource materials (Lepelaar, 2024). However, no found material is shown to level the stiffness and weather resistance of steel, at least without adding (fossil) based additives that make recycling technically impossible.

In my research, I came across many long-existing materials as wood (already 'climate neutral') and bricks (with strong emissions). But in a qualitative design, these non recyclable composites would be the only promising alternative for steel, without fully compromising in product quality and essential requirements.
And if a product is non-recyclable, it might be 'climate neutral' from its emissions in production, but is not circular in End-of-Life, and does not realise a circular economy.

Circular and Reuse
However, in long-term potential durable products, many designers understand that this biocycle approach is not the best suited for circularity of constructive products. The butterfly diagram (Ellen MacArthur Foundation, n.d.) teaches us that for durable products, should be aimed for >35 years lasting materials, finding circularity through the technocycle. This means that the main parts of a solar mounting product should be focused on reuse, repair etc. Eventually, providing for reuse and recyclability is more important than minimal emissions in production.

To enable a circular economy, many producers stay on a course of scaling, and find their sustainability in transforming all or many parts of the supply chain to a circular approach.
For a weak form of this circularity, international production and recycling of steel could create a viable circular handling of products, becoming only climate neutral if the process of recycling or making steel can be done with green hydrogen.
As green hydrogen is depended by renewable energy, it first starts as blue hydrogen via carbon capture (Titirici et al., 2022) . When a fast increase in the amount of green hydrogen would occur, energy production and materials such as steel come available as climate neutral options.

But in the potential of slower hydrogen increase, the roadmaps of Arcelor Mittal and SSAB show us that full production could be neatly realised just in 2050. Green steel is nowadays used as (yet debatable) climate neutral implementations by the solar market (Van der Valk Solar Systems, 2024), but demand growth will likely outpace supply (Baroyan et al., 2023).

Another circular approach for solar mounting products, to reach climate neutral products by 2040, is to simply produce all minimal necessary solar mounting products with one-time emissions, but by 2040 have set up a fully realised reuse system. Then, new products (barely) don't have to be made, and only reuse services need to be climate neutral.

Appendix H: Spatial Constructions for Solar Energy

Besides the supply of PV and the mounting solutions created by the market, another practical aspect of solar mounting is relevant: the spatial arrangement. Within the arrangement of physical space, there are three considerations to take into account.

Solar location

Besides the described solutions of installing solar on buildings (paragraph 5.2), there are of course other locations to put to use for solar. TKI Urban Energy et al. (2022) divide all of the area potential into buildings, infra, land(scape) and water.

The *infrastructure* applications can be divided into placement of PV panels on dikes, sound-walls, landfills or parkings, and integrating solar in streets or vehicles.
The applications in *landscape* can be explained as solar parks on available (wide)lands or as agriculture integration.
And *water* applications aim on floating solar parks on inland and offshore waters.

Structural potential and net congestion

The (mass) availability of certain locational types and the technical development in installing solar at it together determine the short term and long term potential of the location.

For infrastructural projects, mounting solutions often have to be custom developed or strongly integrated, to serve for the variety of infra-circumstances and constructional context.
As installation on land on itself have all the constructional freedom, in general, this type of installation is always possible. Only for multifunctional integration, development is ongoing.
For projects on water, although widely 'available' as space, the circumstances are quit challenging. Product development for solar is limited, and awaiting flexible PV development.

Structural Roofs

According to the RVO (2023), the technical potential of roofs in the Netherland is circa 725 km2, from which 50 km2 on parking lots. However, this technical potential is achievable with different amounts of limitations and structural interventions. As presented in figure H.1.

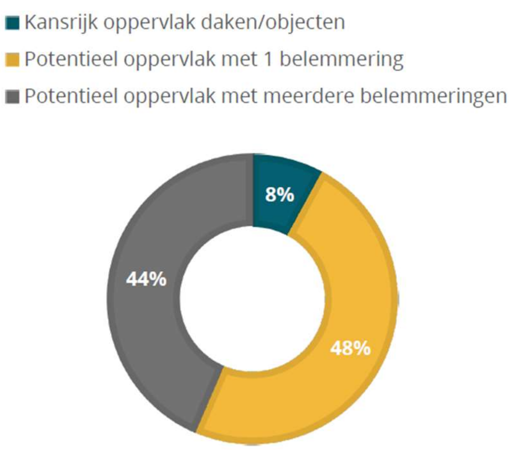


Figure H.1: Probability of solar energy within the technical potential (RVO, 2023)

For utility buildings, Systemic et al. (2021) describe how, heavy limitations for PV instalment can occur for 4 to 26% of a certain building type.
Meaning that in general, 75% of buildings can be used with only simple interventions.

These two sources make clear that a significant amount of roofs in the Netherlands is or can become suitable for solar energy installations, with minimal technical interventions. But it also shows that filling every roof is an illusion, as certain structural limitations are simply unworthy to fix.

For utility buildings, Systemic et al. (2021) made an overview of the percentage of no limited, slightly limited and heavily limited implications per building type:

Figure 3: Probability of solar energy within the technical potential (RVO, 2023)

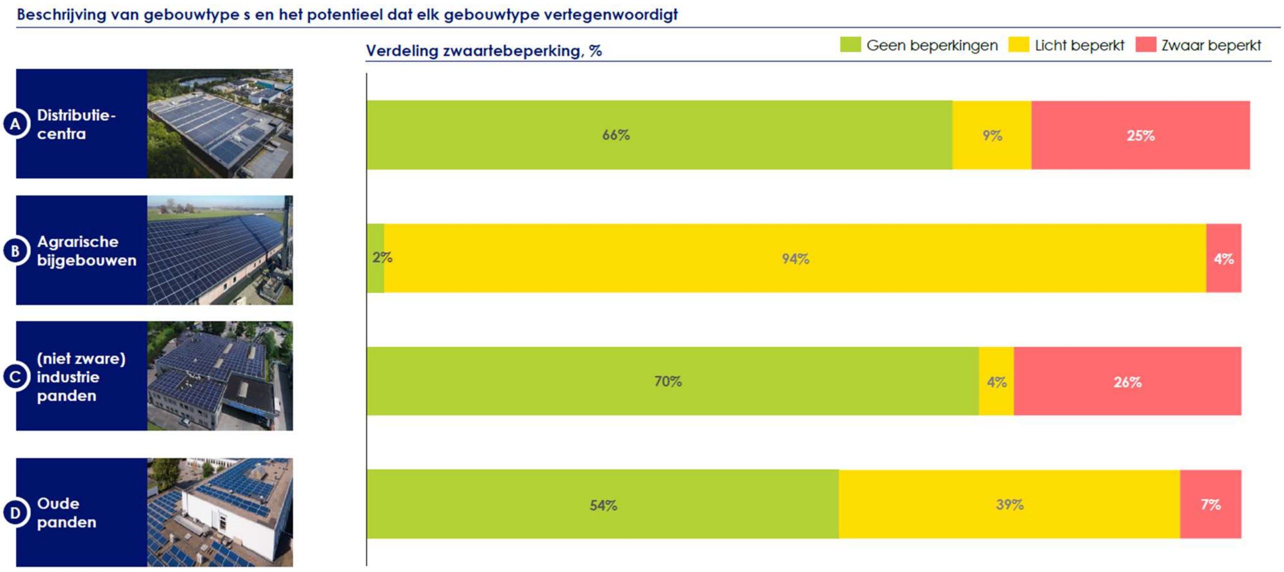


Figure H.2: Limitations per utility building for solar installation (Systemiq et al., 2021)

These figures make clear that a significant amount of roofs in the Netherlands is or can become suitable for solar energy installations, with minimal technical interventions. But it also shows that filling every roof is an illusion, as certain structural limitations are simply unworthy to fix.

Grid congestion
Specifically in the Netherlands, the connection of solar fields (and other electrical fields) to the grid is a growing limitation. In 2023, the RVO (2023) concluded that around 30-40% of the technical potential in roofs has to deal with such limitations. Although being an important factor for the pace of realising solar fields, deep analyses of the effects of grid congestion have been pushed out of scope for this design project.

Planned function of space
Besides the availability of spaces and the technical possibility to install solar, there is the need for prioritising valuable function of space and zoning plans. Besides the production of energy, there are other important societal functions to spatial usage as such nature preservation, food-production, building, infrastructure, social practice or even quality of view.

As high conflicts of interest are currently more present in landscape arrangement of natural areas, agriculture and housing, the Dutch government right now expresses a preferred focus on solar installations on roofs (TKI Urban Energy, 2022).

But also for roofs, there are a view alternative (or complementary?) functions that do compete with a choice for solar energy. Nationaal Dakenplan et al. (2023) describe four major functions of roofs: water management, social design, biodiversity and energy.
Each of these targets can significantly benefit from a planned function on roofs. Therefore, some installers and developers are promoting more multifunctional solutions along side solar energy.

Sedum and solar
The one seriously implemented is green solar roofs. For this, the roof is often filled with non-ascending greenery as sedum, along with the installation of PV panels. There are some suppliers promoting fully double layering (filling all empty space under a panel with sedem), for the argument of cooling the PV panels. But, according to Catalano et al. (2021), an maximised filling of the roofs surfaces causes too much shading, and limits the vegetation.
A well performing combination of both greenery and solar functions therefore always goes at the expense of the maximal performance of the individual function.

Other mentions of similar key drivers:
The TKI Urban Energy et al. (2021) report identified the same key drivers 1 and 7 as challenges for the Dutch solar development, together with system integration to meet user needs (key driver 3) and circularity of PV and accommodating products (key driver 1 and 6).

Appendix I: Solar Mounting Solutions

Roofings & orientations

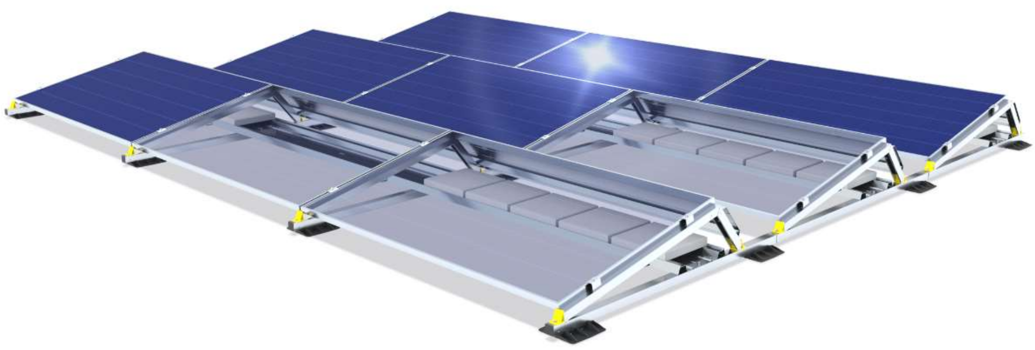
When it comes to the mounting of solar-panels on buildings, there is a general distinction made between residential (private) with small-capacity installations and utility buildings (business) sometimes small, but often larger capacity installations. Besides these somehow standard category of buildings, under the category 'roof' is also noted carports and unique buildings with complex surfaces on top.

PICTURE (residential vs utility)

Then there is three types of orientations of roofs and accommodating solar-panel placement that are used. The east-west orientation of two symmetrical solar panels, one suited for a highly efficient solar production, with a good receiving distribution over the day. Another commonly used solar panel orientation is an universal fixation to the south. This orientation has the best efficiency for a singular directed mounting.

Figure I1: Sunbeam Nova east-west system (Sunbeam, n.d.)

In other additional or restricted cases, the orientation of a solar panel can also be to the south, still offering a relevant production of solar energy. Or a system can be made flexible/moving, changing orientation with the sun's location. Although more efficient in production, the latter is most often unbeneficial in net-gain or costs and maintenance.



FigureI2: Sunbeam Nova south system (Sunbeam, n.d.)

Mounting solutions

Besides the market distinction between residential and utility, and their orientation for solar-panels, these buildings consist of a variety of different roof-types. For the actual roofs, we can make a distinction between flat-roofs and pitched roofs.

Flat-Roof mounting

For flat-roofs, the solar panels are generally mounted on an interconnected beam structure that either stands on the roof and is secured by weight, or is anchored to the roof.

Figure I3: Flat-roof (Sunbeam, n.d.)

Figure I4: Pitched-roof (Sunbeam, n.d.)

Pitched-Roof mounting

On buildings with pitched-roofs, solar panels are generally mounted on solely-fixated beams that are placed on the roof either by mechanical fixing (screws) to the roof surface or hanging/ fixating to the roofbeams.

Facade mounting

Besides mounting on roofs, there are also mounting solutions focused on attaching solar-panels to the facades of (mostly utility-) buildings. The solar mounting on facades of buildings is a quit newer segment. But in general, it seems like it mounts the solar panels on a set of beams, fixated against the existing facade.

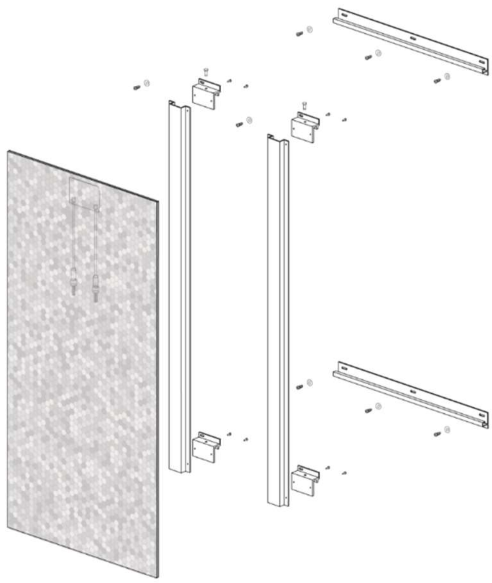


Figure I5 acquired from Solarix (Solar Facade Mounting System, n.d.)

BIPV

Another new and developing sector of solar-mounting is prefabrication and Building Integrated

PhotoVoltaic's (BIPV). This type of mounting is not focused on mounting panels onto a building, but integrating the solar panels (or cells) in a building element that is installed/build into the building.

This type of solar mounting can potentially take on an unlimited amount of embodiments, integrating solar-panels in any building element that faces the outside (walls and isolation, roof-surfacing, roof-tiles, windows) or replace such elements (become the wall, window or roof).

A special notice should be given to customised solar mounting solutions for unique building surfaces or structures, not often carried out with panels, but with integrating solar film. This fits the techniques often underlying the search for BIPV solutions.

Figure I6: BIPV as coloured windows (Wild, 2014)

Carport

At last, there is a mounting structure that is worth mentioning when talking about the roof-types: the carport. It is meant to mount the solar panels at a certain height, to store cars (or other things) below, and therefore also function as a roof. Besides using solar panels, carports can also apply BIPV into more luxurious versions.

Although a similar solution exists in agriculture and land, and the carport can be considered as part of infrastructure, the general market tends to see it as an extension to roof mounting.

Figure I7: Carport with PV Panels (AmperaPark, 2024)

Appendix J: PV technology interview

Interview with Arthur Weeber

Appendix K: Solar Energy interviews and Fair

Interviews with Solar Industry Stakeholders

Interview Arthur Weeber:

De huidige PV-dominantie, en opkomende technologieën.

- c-SI blijft voorlopig de grootste?

Als je ze in kunststof materiaal maakt, kun je deze ook gwn oprollen. Als je naar 20mu gaat, is het net papier en volledig flexibel. Energira (bedrijf in westknollendam), die hebben goed buigzame PV modules.

Ontzettend huiverig voor 'rollen cellen' plaatsen op daken. Dat gaat klapperen. Die dingen ga je integreren in bouwelementen, dan is flexibele zonnecellen wellicht handiger is, gedeeltelijk te vervoeren. Als je kijkt naar wat er nu flexibel te koop is, dan is het rendement nog lager.
Ik denk zelf dat (ci gest dood is), perovskite productie start wel op, maar dan praat je wel over glasplaten.
Flexibiliteit voor op je dak, geloof ik niet. Maar in de toekomst zonnefolie (tandem of tripel) van perovskite (als die technologieën), dan wel geïntegreerd in een bouwelement. Geloof niet in dakpannen, maar dan eerder als een plaat.

Dat je het op je dak spijkert, daar geloof ik geen zak van. Maar ook met ci-Si toch customised product. Dus later oplijmen, ja oke, maar integreer het dan in het bouw-element. Ik zie steeds verder gaande integratie van PV in allerlei bouw-elementen.

Groter wordende panelen:
Grotere plakken, maar juist kleiner gesneden. Je hebt een zeker afstand tot de randen nodig. Water dringt toch een klein beetje naar binnen. Kleinere plakken, hogere vulgraad, interconnectie technologieën. Twee soorten modules, die grotere voor de powerfields, en de kleinere voor de residentiële markt. Die kleine worden in theorie dus geïntegreerd.

Niet helemaal waar dat de initiatieven in EU anders dan silicium zijn. Bijna allemaal zijn ze no silicium. Cell uit china heet topcon. In EU meer op hetero-guntie zonecellen als opstap naar tandem. 'European Solar manufacturing council, hebben het over 100GW in 2030, gaat Europa nog veel te langzaam vergeleken met de rest'.

- c-Si hier geen grote productie, andere thin film, of perovskites wellicht wel. Hoe opschaalbaar en snel?

c-Si moet je zuiveren, impliciet een achterstand op perovskiet of organische pv. Kan me voorstellen dat silicium ergens op Nexwave, groeien plakken op substraten. Dan zaag je ook niet. Al een heel stuk duurzamer. Silicium films, crystallijn. Perovskiet bevat nu nog lood, maar als je het weghaald verliest het veel rendement.

- Flexibele oplossingen, kleuren oplossingen, er wordt van alles gemaakt. Is het echt nodig?

Combinatie: Powerfields, plekken echt gericht op grote energie productie. Maar ook lokaal, waar je het lokaal wil gebruiken qua energie. Richten op integratie, multifunctioneel gebruik van oppervlakten. Heel erg afhankelijk van architectuur en lokaal.

- Veelbelovende tandem oplossing, in hoeverre verlies je daarmee individuele eigenschappen als flexibel etc?
- Is een tandem oplossing efficienter dan twee andere panelen los van elkaar?

Is ook echt nodig om efficientie doelstellingen te halen. De panelen, constructiematerialen en installatiekosten vormen op dit moment het grootste kosten deel.
Dus efficiëntere panelen verlagen de kosten. Huidige kosten zouden nog minimaal factor 2 naar beneden kunnen, efficent rendement is daar een van.
Enerzijds opschalen en standaardisatie, als maatwerk en unieke oplossing.
Ookal heb je flexibele panelen, dan wil je nog steeds frames/rigide toevoegen.
Maar ruimte is schaars, dus hogere efficientie is toch beter, nuttiger. Als je het goed integreerd, minofmeer onzichtbaar maken, daar is nog wel een hoop voor nodig.

Panelen vervangen, voor nieuwe met hogere efficientie. Meer dan een factor 2 verbeterd sinds 20 jaar. Als een module toch ook goed recyclebaar gaat zijn, en de schaarsheid, dan zou vervangen beter moeten kunnen. Zeker ook naar de volumes die verwacht worden in de toekomst, 3TW per jaar (factor 0 van wat het nu is). Wereldwijd factor 50/60 meer zelfs.
Dat kan niet meer met de huidige technologieën.
Maar de technologie gaat ook super hard.

- Thin film/niet panelen oplossingen: moet het niet nog steeds onder een hoek?

Heel belangrijk dat het vuil eraf spoelt. In zuid-europa nog meer last van sahara zand. Altijd goed bij PV modules.

End of Life:

- Kwestie van materialen die niet los te halen zijn van elkaar?

Ginco (chinees bedrijf zegt goed tte kunnen recyclen). EU richt iig op duurzaamheid en integratie.
Footprint van de Chinese modules wordt ook veel beter, China bereid zich voor op carbon footprint reglementen uit EU.

Critical materials:

- PFas als laag, waar precies en waarom?

Building Integration PV:

- Waarom zouden we dit willen, behalve de non-acceptatie van mensen als het niet geïntegreerd is?
- Is er ooit geëxperimenteerd met geïntegreerde batterij/storage technieken?

Daar wordt over nagedacht, zijn ook eerste resultaten mee behaald. Speciale soort hoogcapaciteit batterijen in PV. De elektriscche auto, eventueel ook ontladen. En ik kan me ook voorstellen, dat je ook een stukje energie opslag in je paneel kan doen. Dat het paneel per minuut bijv stabieler wordt. De minuutfluctuaties eruit.
Natuurlijk wel in de 'boze buitenlucht', kijken in hoeverrre je kunt integreren.

Toekomstige duurzaamheid behalen:

- Effectief, duurzaam en ruimte-slim opschalen vs snel & efficiëntie verhogen?

Ik zie al oppositie bij PV velden. Egaal van kleur zou al een grote winst zijn. Dat worden nu de meeste modules. Monumenten, uiterlijk van een stad. Alles is mogelijk.

Industriële omgevingen, agri-omgevingen, ‘PV boven de wijn-druif’, daar hebben we het echt meer over velden. Verticale zonnepanelen in agrivelden, combinatie met dieren. Niet een hectare helemaal vol maar echt meervoudig landgebruik.
TKI urban , potentieel ruimtegebruik PV, rapport uitgebracht, potentieel van Nederlandse PV integratie.

- Hergebruik en verplaatsing van panelen?

‘Alles wat je denkt is mogelijk’ – Arthur Weeber. Het komt er in ieder geval heel dichtbij. Gerkromd, kunststof, volledig recyclebaar.

Re-use liefst wel lokaal / europees. Want in africa EoL ook geen idee. Gebouwen die over een X aantal jaren gaan rennoveren/slopen, daar tijdelijk reuse neerleggen.
Rendement van PV stijgt nog ieder jaar met 0,5%.
Vervanging wordt mogelijk ook economisch aantrekkelijk.

c-Si gecombineerd met dunne film, gaan we de 30% voorbij. Tandem, of tripple. Maximaal rendement in de wereld gehaald is dicht tegen 50% aan. Met stapeling van heel veel cellen. Doorontwikkeling van goedkopere ontwikkeling.

RVO rapport voor de hoeveelheid PV die geïnstalleerd gaat worden, ook voor 2030, 2035, 2040. Nationale solar trendrapport.
Wellicht nog referentie van nationaal plan energiesystemen – van RVO uit.

Wat de Energie Energy Transition zegt, forget it.

Rol van de groothandel
Naast dat ze zelf ook een zonnepaneel systeem aanbieden, bieden ze ook een PVT systeem. De groothandel maakt ook een eigen configurator, daarmee kunnen ze een volledige roadmap bieden aan de huisbezitter. Dus de stappen in de komende jaren die interessant zijn of worden voor de eindklant, op basis van gebruikers-data. Zo wordt er gemikt op in jaartal X energieneutraal zijn.

Toegevoegde waarde
Alleen logistiek is niet genoeg waarde toevoeging als groothandel. Waardetoevoeging zit bij de eindklant, installateur en fabrikant.

- Eindklant: Klant ontzorgen. Eigen configurator, data analyse en digitale service/garantie management. Producttypes: maximaal rendement, maar ook wat vaker stuk, dus leveren service voor reparatie. (Die service wordt wel weer extern uitbesteed vanwege capaciteit).
- Installateur:
  Maken en verkopen van geassembleerde / prefab onderdelen.
  Het samenbrengen van de producten uit het product-systeem. Directe levering op installatie locatie als één pakket.
  Service-calls overnemen voor bepaalde producten. Vervangend product gelijk meeleveren bij gedetecteerde garantieclaims.
  Korting bedienen bij groothandel (massa).
  Samenbrengen van aanvragers en installateurs.
  Door configuratie-tool en roadmaps van een enkele naar een meervoudige klant-levering over de jaren (5 a 6 keer).
- Fabrikant: Bulk-levering naar minimale hoeveelheid locaties. Op de markt zetten van producten.

Toekomst van installatie-branche
Keten-integratie
Je ziet een ontwikkeling waarbij de grote vissen de kleine vissen opeten. Dat is een teken dat de markt is voldaan en het nu efficiënter en met minder kosten moet. Ook gaan groothandels meer installateurs overnemen. De groothandel en fabricant levert nu nog B2B, maar er gebeurt meer B2C. Het opleveren van totaalpakketten bij de eindklant, en slimme planning van resources, gaat echt groeien.
In de toekomst plaatst(exclusief aansluiten) de groothandel wellicht de producten, de steigers en doet de opbouw en afbouw om de installatie heen. Zo kan de installateur maximaal veel installeren. Dat biedt ook ruimte voor emballage en retour-stromen.
Er is een enorm tekort aan installateurs, daarom wordt er ook meer en meer prefab gemaakt, met name in de warmte, niet zozeer in de zon. De zon-installatie is redelijk gestandaardiseerd en minder woning afhankelijk.

Tegelijkertijd is het een conservatieve markt. De groothandel levert de bekende producten, en dat is wat de installateur wilt.

Service en reparatie
Ik denk wel dat groothandel steeds meer communicatie en service management gaat overnemen. Ook is bij stroom en zon de service-management minder kritisch. Bij een storing van zonnepanelen heb je nog gewoon stroom en dus kan er een dag of twee overheen voordat

reparatie gebeurt.
De conservatieve houding maakt de installateur ook huiverig voor nieuwe producten, die zichzelf qua betrouwbaarheid nog niet hebben bewezen. Want straks levert het over X jaar veel service/reparatie gedoe op.
Service en reparatie worden ook steeds meer en meer uitbesteed. Er komen meer aparte installateurs en servicemonteurs. De originele installateur biedt bijvoorbeeld ook externe servicepakketten aan.

Zonnepanelen

De panelen zelf

Aanbod gestuurd (in Nederland). Aanbod is deels afhankelijk van China productie opschaling maar ook van bemating normen in Duitsland (en China). Verder wordt vooral het vervangen/repareren van oudere panelen lastig. Er zijn wel wat partijen die op maat gemaakt kunnen leveren, in de toekomst wellicht interessant.
Residentieel draait het bij zonnepanelen om oppervlakte gebruik. Bij utiliteit om de procentjes: efficiënte, minder onderconstructie, snellere installatie, goedkoper.

BIPV

Gevel voor ons steeds interessanter. Belangrijk dat het mooi is, maar kan ook door niche van productplaatsing komen.
In 2040 zouden zonnepanelen zomaar naar de bouwmarkt kunnen gaan. Geïntegreerd met de isolatieplaten (sandwich systeem). Stekker eraan en klaar, niet armoeien met lossen panelen en montagesystemen. Uitdaging is uiteraard levensduur (25 jaar vs 75 jaar pand). Hoe los je dat op?

Zon-efficiëntie

Momenteel kan je 30% van een huis energievraag met zonnepalen stabiel dekken. Met smart-products in de toekomst (heb ik begrepen) 70-80%. Lokaal opwekken wat je gebruikt wordt de grootste uitdaging. Meer capaciteit panelen leggen voor je winter-piek energieverbruik niet rendabel (zonder saldering).
Voor bedrijven is het, met slimme EMS systemen, een stuk rendabeler maximaal te leggen.

Interview Projectontwikkelaar

In eerste instantie deden we particulier, maar nu alleen nog maar zakelijk. Dat gaat van 50 tot 5000 panelen. Ook zijn we een tweede tak aan het ontwikkelen voor carports. Dat is echt een zichtbare ontwikkeling, het dubbel ruimte gebruik, dat wordt als gunstige methode gezien.

De markt*: Vanuit energie of vanuit klimaat? Wat motiveert tot zonnepanelen?*
Zakelijk. Het draait uiteindelijk allemaal op onderscheidend vermogen. De ene partij onderscheidt zich puur op prijs, de ander op klimaatneutraal. Dan heb je ook nog veiligheid (Vca-certificatie) en een gezonde werkdruk.
Er spelen veel verschillende drijfveren bij klanten. De hoofddrijfveren zijn wel de euro's. Er kan heel goed een wens vanuit huurders/vastgoed komen om te verduurzamen, aangevuld met de wens van vastgoed eigenaren om te voldoen aan regelgeving en imago. Maar uiteindelijk draait het erom dat het uitkomt. En vaak ziet men dat het een sterke investering is.
Een andere drijfveer is ESG, de verplichte vooruitgang daarvan in een bedrijf. De medewerkers die daarop zitten moeten steeds meer en meer vinden om te doen. Zonnepanelen, of extra zonnepanelen in carports zijn dan interessant. Die ESG en de maatschappelijke druk neemt toe.

Particulier. Particuliere installatie gaat nog meer om de prijs en de laagste offerte. Het energielabel van het huis kan snel verbeterd met zonnepanelen. De particuliere sector is moeilijk opschalen, omdat je dan toch naar 2 installaties per installateur per dag zou moeten.

Energie-vraag *Efficiëntie van de panelen. Maximaal energie-gewin of toch meer prijs / gebruiks gedreven?*

Dat is verschoven. Vroeger was het zo dat je het precies moest matchen (filosofie op dat moment). Je keek dan naar het maximaal vermogen per paneel. Om met de minst mogelijk aantal panelen het nodige vermogen te halen. Dat gebeurd alleen bijna nooit meer.
Het is gegaan naar een dak zo vol mogelijk leggen, voor de maximale opbrengst. Want je bedrijf gaat toch nog verder elektrificeren. Echter, nu door de netcongestie gaat de vraag weer terug naar het balanceren met niet alleen gebruik, maar ook opname, opslag, piekmomenten in gebruik en opbrengst.

Bijvoorbeeld: Door netcongestie problemen kan je niet maximaal panelen plaatsen. En een batterij plaatsen om extra zonnestroom op te slaan voor piekmomenten is niet financieel gunstig. Dan toch een klein beetje van het net afnemen, en een lagere hoeveelheid panelen.

Aanpassing *Gebeurt het dat een niet volledig gevuld dak, toch panelen worden bijgelegd?*

Jazeker, er wordt bijgebouwd op daken waar al licht. Als een bedrijf bijvoorbeeld van het gas afgaat. Je bouwt dan gewoon met een nieuwe installatie vorm verder. Dat is geen probleem.

Repowering
Repowering van de installatie gebeurt regelmatig. We zien het veel bij particulieren. 10 jaar geleden een paneel aangeschaft, en al lang en breed terugverdiend. Dan kan je een nieuwe set leggen. Bij bedrijven zie je dat minder, die kijken eerder naar nog verdere uitbreiding (carport, ander pand). Of velden aanleggen op leeg terrein.

Prijs *Aandeel van installatie in de prijs?*
Doorslaggevende factor? Verbonden aan installateurstekort, of voornamelijk installatie-tijd?

Er is een tekort aan elektriciens, niet aan aansluiters op het dak. We hebben wel certificering voor de elektricien. Een nieuwe elektricien zoeken is moeilijk, daarom doen we ook zelf opleiden.

Bedragen voorbeeld: 500 zonnepanelen, 50 cent per wat piek rekenen, waarvan 15% stellage, 12,2 % de installatie arbeid. 34% zonnepaneel.

Verdere prefabricatie van dak-stellages zie ik niet gebeuren. Dan moet ik hele stellages op het dak gaan hijsen? In de dakkapellen, carports etc zie ik er wel nut van in. Dus vooral de bouw.

Panelen/Trends
Panelen worden steeds groters, en de paneelprijs is nu heel laag, maar die zal ook wel weer iets stijgen. De nieuwe type panelen, die echt door een andere productie hogere efficiëntie halen, zie ik de komende 10 jaar nog niet gebeuren.

Stukje carports gaat toenemen. Om daar een montagesysteem voor te maken heb ik zeker gevraagd. Veel solar-mounting wel druk mee bezig.
Een andere trend zie ik in verticale zonnepanelen. Ook op het land. Het is een super efficiënte manier voor zonne-energie.

Rolverdeling *Installateur, project ontwikkelaar, groothandel. Wie gaat wat doen, de ontwikkelingen?*

Ik heb zelf geprobeerd een onderhouds-afdeling op te zetten. Niet gelukt, dus nu uitbesteed naar een derde partij. Waar wij YY installaties (commerciële) in onderhoud hebben, ondergebracht bij iemand die er 4xYY had (dan zit je over een treshold van 2 man permanent op pad). Nieuwbouw is echt compleet iets anders dan onderhoud, dus dat wordt logisch apart gedaan.

Ik zie de service-contracten etc niet bij de groothandelaren zoals wij mee werken. Wij kunnen het spelletje zelf. We hebben geen service nodig. Voor partijen die net beginnen, en kleine installateurs snap ik het, de ontzorgings-pakketten. Wij zitten op het volume, om te zorgen dat we veel kunnen afzetten in een efficiënt proces.

Interview Aluminum Producent

Energie
Low-Carbon aluminium wordt nu al geproduceerd met een CO_2 emissie van 4kg CO_2 impact per kg alumium. Dat is relatief laag. Vergeleken met chinees aluminium (kolen-energie), wat zo 20kg kan zijn.
Het verschil is de energiebron. Die laag-koolstof aluminium wordt geproduceerd met waterkracht. De vraag naar dat aluminium is nu al soms groter dan het aanbod dat men kan leveren. Dus moet er via meerdere partijen hetzelfde 4kg CO_2 laag-koolstof aluminium ingekocht.

De energiebehoefte bij recyclen is maar ~5% vergeleken met primair aluminium. Voor productie van aluminium wordt ook naar verdere stappen gekeken in waterstof en andere energie.

Materiaal bron
Grondstof is bauxiet, gesteente met name gewonnen in andere delen van de wereld. Ook daar gaat het met name om de energiebehoefte, daar wordt ook daar naar gekeken. Omzetten naar aluin-aarde/alumina. Verreweg meeste energie bij gebruikt.

Recycling
Voor schroot en gebruikt aluminium kan je, door het energie verschil, uiteraard lagere CO_2 waardes rekenen. Maar er zijn verschillende calculatie methodes, wil je bijvoorbeeld het schroot uit fabrieken net zo laag waarderen als gebruikt aluminium.
Aluminium profielen maken altijd ongeveer 20% process schroot. Soms gewaardeerd als 0, maar deze fabrikant vindt dat niet terecht. Het heeft niet een volledig nuttig leven gehad, dus waarderen het anders.

Grootte van de recycle markt
Op dit moment zouden we eigenlijk veel meer schroot willen hebben. Aluminium gaat veel langer mee, dus zo snel krijgen we het niet terug. Geveldelen bv, daar geen veel jaren overheen. Het zou wel kunnen dat er op een gegeven moment dergelijk aanbod is om in ieder geval veel meer recyclet vraag te dekken.

Schroot aanbod
Er zijn tussenhandelaren, schroot verwerkers. Fabrikant zelf ook niet zo goed in het scheiden, je moet echt goed schroot hebben. Dat scheiden is iets wat gedaan wordt door schroot verwerkers. Daar zijn er een x aantal van in de Benelux.

Closed-loop recycling
Dat gebeurt nu al. Bij sommige partijen, die redelijk wat schroot ook produceren, omdat er gezaagd wordt en er afval ontstaat. Als dat enigszins met grotere hoeveelheden gebeurt, dan is er een aparte bak met schroot: puur goed aluminium. Voor het innemen wordt dan ook uitbetaald.
Soms wordt ook bij een specifiek productie-project een serie oude projecten binnengehaald. Dat is goed uitvoerbaar, vaak is de originele legering dan ook nog goed bekend.

Compensatie
Onbekend met compensatie, dat ligt voor zover bekend tot nu toe altijd bij een eindklant.

Appendix L: Shell's scenarios to Industry scenarios

L.1 Standardised Mass Energy

PV Market:

The solar market experiences exponential growth, by ongoing advancements in the performance of PV panels and standardisation of products for scaling. To meet the rising demand, panels are produced in a wider range of standardized sizes, with major production located in China and expanding across Asia, Africa, and Latin America. To create added value, the European-based producers focus on performance-enhancing and sustainable manufacturing. The market and the EU gradually set new standards for quality and innovation.

Service:

In *Standardised Mass Energy*, the solar industry delivers large scale project execution, by deeper integration of PV systems, products, installers, and supply services. Certified installers play a crucial role in ensuring safety and quality standards, driving consolidation in the solar mounting market. Streamlined installation processes and technological advancements enable the fastest massive installed capacities. The delivering of transparent and responsible production of energy is the agreed value for investment, driving low-carbon industries.

Clients and Location:

Large-scale solar projects become the norm, with governments, housing organizations, and businesses collaborating. They create energy projects that provide secure and reliable energy services for communities and industries. As roofs provide for an accepted and sufficient area for meeting solar energy ambitions, the main emphasis is on full coverage of roofs and buildings but also includes other solar fields. Solar energy is rolled-out whole districts at once, offering green energy to its citizens and the grid.

Hydrogen and Energy Infrastructure:

Standardised Mass Energy, you will see a significant growth in hydrogen as a clean and viable energy carrier, supporting the expansion of the PV market. Investments in hydrogen production and infrastructure enable renewable energy sources such as solar and wind to produce green hydrogen at scale. This boosts new low-carbon production industries of green steel and other materials. Efforts to improve grid infrastructure address grid congestion issues, ensuring efficient transmission and distribution of renewable energy. Mass solar energy project play an important roll in creating energy security while reducing reliance on imported fossil fuels.

Production Industry and Carbon Pricing:

The production industry undergoes a transformation towards low-carbon and sustainable results. Carbon pricing mechanisms stimulate companies to gradually reduce their carbon footprint and to invest in alternative practices. To reinforce this low-carbon production, policies against carbon leakage are implemented, but exceptions for international depended products are made, just as PV panels themselves.

Through Standardised Mass Energy, the PV market embraces standardisation, innovation, and scalable production, maximising the installed capacity of renewable energy and serving the way towards a cleaner, more sustainable future of society.

L.2 Circular Energy

PV Market:

Circular Energy sees the emergence of responsible business in the PV market, characterized by investments in PV transparency and sustainable production practices. With a focus on PFAS-free, lead-free, and recycling critical materials, the EU stimulates the road towards fostering a sustainable and transparent PV industry. As China will continue to serve as the main supplier of PV, it will comply to new sustainable standards and develop sustainable PV production for panels, just as the EU. Investments and innovations enable circularity throughout the PV lifecycle, from production to end-of-life disposal, ensuring minimal environmental impact and long-term independency.

Service:

The entire solar industry takes proactive steps towards climate neutrality, offering sustainable PV panels, converters, mounting and all accommodating products. From production to transportation and installation, the entire supply chain is optimized for sustainability, aligning with the climate-neutral goals in all sectors. New products, functions and value is developed to serve sustainable business. Certification of climate-neutral products and transparency on carbon footprints drives the solar energy service, and boost the widespread availability of climate-neutral energy.

Clients and Location:

Partnerships with PV producers and installers ensure the supply of climate-neutral reuse solar energy solutions, offering a new form of value: climate neutrality. This serves project developers seeking competitive and low-carbon results. It emphasizes the importance of a holistic use of space and resources, balancing the potential of roofs and land between nature, social-aspects and optimised solar energy.

Energy Needs and Infrastructure:

Besides how significant investments in energy independence drive innovation in nuclear, hydrogen, and battery technologies, the society's focus is on leveling and decreasing energy needs. With the isolation of buildings and reduction of household energy usage, the increase in energy need is limited. Low-carbon production facilities and smart products become essential to comply with the peak demands in the energy grid.

Production Industry and Sustainable financing:

Transparency on carbon footprint and ecological costs becomes essential, to comply to increased carbon pricing and policies against carbon leakage. In *Circular Energy*, the production industry discovers the value of circular design principles in the supply chain. New economic value is found in enabling function over product, leading to alternative value creation as minimising, reusing and product-less initiatives.

Through *Circular Energy*, the solar industry embraces sustainability as a core value, paving the way for a cleaner, more resilient future for generations to come.

L.3 Scramble for Energy

PV-Market:

Solar panels, primarily sourced from China and other global suppliers, flood the market with varying levels of quality, efficiency and price. This price and product diversity democratizes the solar market, making different forms of solar energy accessible to a wide range of consumers. Due to a growing energy scarcity, the high differences in availability, quality and performance of available solar creates a growing energy inequality. small but growing segment of highly efficient integrated panels emerges from European producers, catering to consumers seeking premium quality and performance.

Energy Needs and Infrastructure:

A lack of centralised energy infrastructure and the inconsistent daily production of solar power leads to a rise in Energy Management Systems and energy-as-a-service solutions. These technologies enable consumers and businesses to optimise their energy usage and storage, and mitigate the risks of grid instability. Energy-as-a-service companies apply a mix of local renewable energy sources, grid connectivity, and energy storage to deliver reliable and consistent power to big corporates, filling the gap left by the inadequate infrastructure.

Service:

The solar industry responds to the challenges posed by fragmented energy infrastructure by providing a wide range of panel types and installation solutions. From low-budget and temporary options to durable or customisable applications. Although very chaotic, all these alternatives do democratise the access to solar energy. Energy Management Systems and home-battery solutions play a premium role in addressing solar intermittency, offering consumers control over their energy consistency. Consult and support on choosing solar products is provided by affordable AI consultation at home.

Clients and Location:

The sales market of solar energy is complex, including many budget-conscious private consumers, bulk resellers, and businesses seeking energy-as-a-service solutions. This fragmented market presents both challenges and opportunities for solar companies. The sales range from budgetary and simple quality solutions for installing solar just anywhere there is useful space, up to expensive adaptable structures for energy consistent production fields. Each customer searches the best productive use of solar, exploiting construction- and socially accepted-limits.

Production Industry and Two World Markets:

Industries face challenges like higher energy costs and uncertain trade relations. With the shift towards isolationism and regional trade agreements, there is a resurgence of domestic production as countries seek to reduce their reliance on global supply chains. The main focus is on cost-price reduction and reliability rather than circularity. As technology improves and industries minimise their dependency on international energy and productional supply, they're starting to become more sustainable too. Governments are creating rules to prevent unfair competition from other countries, which helps local industries to grow.

Scramble for Energy embeds the resilience and adaptive qualities of the solar industry. Dealing with the inconsistent trading market and enabling the individual with innovative solutions to uphold solar energy as a viable energy source.

L.4 Power to people

PV-Market:

Facing problems in energy supply, the EU chooses for rapid investment in European PV production, aiming to achieve energy independence and minimising the stretch of fossil fuel usage. However, due to time constraints, all significant portions of PV products are still imported from contracted suppliers in Asia, Africa, and South America. These batches of solar panels and other products from joint purchasing strongly differ in quality and types. European PV production focuses on scalability and stimulating domestic wealth, energy equality and shared initiatives. Emerging technologies like thin-film and perovskites gain traction, alongside efforts to update existing panels for enhanced efficiency.

Service:

With a diverse range of PV technologies and panels sourced through extensive contracting, the solar industry puts its focus on enabling and applying these batches of solar products where they fit best. Fairly distribution of new solar projects is organised to stabilise the grid and minimise energy inequality. Therefore, new solar is mostly installed in bigger regional projects rather than the individual market. Additionally, in the private market, a secondary market emerges for reusing, relocating, and updating solar panels and mounting systems, promoting resource efficiency and longevity.

Clients and Location:

Driven by principles of social equality and environmental stewardship, community-based solar sharing initiatives gain momentum. Housing cooperatives and ESG-driven companies win over solar projects for residential areas and public services, with approval from policies. As energy demands still increase, expansion and efficiency enhancements in domestic solar deployment become imperative. This means that solar gets adopted in underserved districts where the potential returned energy is promising ánd this energy ends up at those who need it the most.

Social Energy and Climate adaptation:

Due to increased risks for energy inequality and societal shortcomings, a shift towards a more socialistic approach emerges, emphasizing collective efforts to provide sustainable energy access for all. Solar projects become integral components of community-driven initiatives, municipality programs, and public projects aimed at addressing societal needs. These projects not only focus on providing solar energy but also incorporate other essential services and climate adaptive actions, including water management, biodiversity preservation, and the creation of green spaces to improve air quality.

Production Responsibility:

Struggling for international independency, industries across sectors shift towards boosting domestic production. The industry creates strict contracting procedures for trading, prioritising local sourcing and production in their supply chain, ensuring greater self-reliance. Companies actively engage in their local communities, driving societal well-being, public projects, and job creation while using circular economy principles as reliable business.

Power to the People recognises the turbulent geopolitical landscape of the Archipelagos scenario, where a global scramble for energy resources exists. Society includes solar energy to balance industrial demands and citizen needs, to grow domestic social wealth, international independence and climate adaptation.

Appendix M: KeyDriver Resource argumentation

M1 : Trends supporting a Standardised Mass Energy scenario

Driver 1 & 2

The development of better and better performing PV keeps going strong, as new technological breakthroughs are constantly coming, such as in 2023 proven efficiency of almost 27% (TU Delft, 2023). Major production comes from China and more and more from Asia, Africa and Latin America. By European market demand for performance, the supply from around the world provides as needed. Including solar panels continuing getting larger (Kennedy, 2022), but deliver a range of standardised sizes for installations purposes.

Driver 3

For reaching solar ambitions, installers costs would have to drop according to TKI Urban Energy (2022). This necessary lowered cost of solar system in manufacturing, installation and operation was determined at 30% by 2030 (ETIP et al., 2021). But as a result of strong business model integration and product innovation, the installing price per Watt for 2030 decreased within its range (1,21-1,82 USD) to the minimum, as predictively modelled by Ardani et al. (2018).

There is a rising human capital of skilled installers, created by a regulatory framework as set up in the European Green Deal (SolarPower Europe, n.d.). Although providing a rapid growth of installed capacity, this growth also demands for quality standards for personnel and the design of multi-purpose and standard systems (TKI Urban Energy, 2022), certified by warranty and insurances, as already executed by SGZZ (2023).

For new buildings, the market embraced the 2023 trend of prefabricated mounting solutions (De Jonge Baas, 2022) and market predictions of robotising the process (De Jonge Baas, 2023).

Driver 4

As determined by TKI Urban Energy et al. (2021), the Dutch residential sector can fully provide for its own total energy consumption through solar energy. Therefore, the consumer market is focused on household energy management systems, batteries and insulation. As solar projects are installed in larger district-oriented projects, every household is provided with a good share of solar energy. Improvement of the electricity grid is supply driven, with infrastructure for district energy sharing and towards industry mass needs. This approach was started with the strategy of faster realisation, steering usage and creating flexibility in the Landelijk Actieprogramma Netcongestie (Rijksoverheid, 2022).

Driver 5

As planned in the European Green Deal, the focus is on electrification with renewable energy and creating supply and infrastructure for green hydrogen (SolarPower Europe, n.d.). Certainly not for all production industry's, but for PV supply, Europe accepts a certain international dependency to the free market and invests money and politics in maintaining bonds with a significant set of Asian and African suppliers and resellers around the world. As the installed capacity in Europe grows, the dependency to foreign production decreases and so policies that give domestic production a competitive advantage rise up.

Driver 6
To enable a massive energy transition, many established industries providing this transition stay on course of scaling, and find their sustainability in transforming the supply chain, rather than the product.
As green hydrogen is depended by renewable energy, it first starts as blue hydrogen via carbon capture (Titirici et al., 2022) . With the fast increasing amount of green hydrogen (Sky2050), energy production and materials such as steel come available as climate neutral options, supported by industry collaboration on recycling. But roadmaps of Arcelor Mittal and SSAB show that full production could be neatly realised just in 2050. Green steel is already used as (yet debatable) sustainable implementations by the solar market (Van der Valk Solar Systems, 2024), but demand growth will likely outpace supply (Baroyan et al., 2023).

Driver 7
With removing size caps on public tenders, the market for solar parks on land is rapidly growing (SolarPower Europe, n.d.). As with rising obligations for solar installation on existing (Vlaams Energiebedrijf, 2023), renovated and new roofs, the solar energy on roofs produces big. Solar energy in general is mainly produced through a balance between buildings and land installed PV, respectively in dense city's and mainlands. As those two applications can provide well for all solar ambitions (TKI Urban Energy et al., 2021), other applications except for carports and BIPV remain a niche.

Driver 8
As solar panels on roofs is the most public accepted form of renewable energy (Rijksuniversiteit Groningen et al., 2021) and this is proven to be sufficient to reach solar ambitions, there is no reason for society to accept large scale installation of more visible solutions. Additional applications as facades and new building will therefore be accepted if visible attractive prefab (De Jonge Baas, 2022) and as effective new 'solar activated' building elements (ETIP et al., 2021). As functionality and performance partly determines sustainable perception, metals are preferred in view (Diego-Más et al., 2016).

M2 : Trends supporting a Circular Energy scenario

Driver 1 & 2
Market and government regulation is demanding for Pfas-free and Lead-free PV, as proven by European manufacturers as Meyerburger (Meyer Burger, 2023). Besides sustainable production, the PV-recyclability and the waste-system are improved for circularity of the life-cycle. By investing in European manufacturing, as the European Green Deal suggests (SolarPower Europe, n.d.), sustainable standards arise, which the supply from around the world follows.
Product development enables the mounting of thin-film, frameless and recyclable PV-panels, for their pure environmental benefits. The thin film PV production shows easier potential in upscaling European production than cSi (ETIP PV Industry WG et al., 2023) and use of critical materials, that can limit the sectors growth (MIT et al., 2015). The shorter life-span of a thin film product is subordinate to its potential performance in climate neutrality.

Driver 3
The solar-mounting industry will strengthen bonds with European PV industry, deeper integrating mounting and PV at the front of the supply chain. So can frameless panels, as seen at Solar Solutions, be integrated directly in sustainable mounting solutions, unlocking alternative structural materials and production, as, for example, bio composites (Otter, 2023). Besides integration, the solar mounting industry includes proper deinstallation and disassembling

services. This will improve reuse systems, and make sure the recycling/reusing potential of 80% per element is actually met (O'Brien, 2021).

Driver 4
An important method in answering the energy needs of the public and industry is the reduction of these energy needs by conservation measurements and improved energy management*. To reach a 100% renewable energy system, the energy demand will undergo mass electrification up to more than 90% in 2050 (LUT University et al., 2019). In total, the electricity needs and supply will grow, but might be temporarily slowed down in order to properly transition in a climate neutral way. This demands wealthy companies and government to cover extra expenses.

Driver 5
As most public solar projects will exist of calls for tenders, the solar energy and its sustainable performance is driven by ESG- and carbon pricing policies. Just as policies and customer demand supporting domestic production and development in the solar industry. To be able to deliver, the EU also stimulated production:
On the case of scarce resources and critical materials, the EU has grown internal mining, but cannot deliver fully. From spilling over 90% of critical materials in 2024 (Rotmans, 2024), the EU has strongly embedded obligations for recycling practices to close its internal loop.
Although pushing out production facilities in 2024 (Kurmayer, 2024), the EU repowered its ambitions and increased the existing finance, for example with the financing of PFAS-free Dutch production (Solarge, 2024).

Driver 6
From strong carbon pricing, carbon leakage policies and domestic production is stimulated. In 2023, the EU started the first expansion of the scope of its Emissions Trading System (ETS) (EUR-Lex, 2023). Also, new laws are prohibiting claims for 'climate neutral' products, when in fact emission are compensated by carbon offsetting (Kurmayer, 2024).
All in all, the industry will produce competitive sustainable mounting solutions for standard panels, with bio and recycled materials. As the inclusion of biomaterials could enhance negative carbon numbers, reinforced compositions and wood are practiced in construction as part of the sustainable roadmaps (Titirici et al., 2022). Current examples are Resysta's biowaste 'timber' (Gadero, n.d.) and biocomposites from Tipwood (bioframe.com, n.d.).

Driver 7
As a result of the bottom-up push for sustainability, the spatial arrangement of solar energy is strictly judged as well, only supporting solar energy locations that do not lead to deforestation or nature reduction*. An important strategy in this, is investing in configuring locations and mounting solutions that do no harm. With applying high efficient solar panels for further minimising space usage (TKI Urban Energy et al., 2022) and a balanced lay-out, no spatial limits has to be expanded (TKI Urban Energy et al., 2022).

Driver 8
In this most bottom-up driven circular scenario, visibility of solar energy solutions is possibly even a proudful aspect. As an individuals or companies low-carbon profile is the norm, a visible climate neutral product is an advantage. Research shows that sustainability is, amongst others, perceived strongly in functional performance and through colour and material (Diego-Más et al., 2016), or could be reconciled by recycled or organic material (De Medeiros & Ribeiro, 2017).

M3 : Trends matching a Scramble for Energy scenario

Driver 1 & 2

The accessible PV Panels for the EU are mainly supplied by the mass solar industry in China and a view other resourcing countries. As the critical materials for solar are still byproducts of largely delved materials needer for other sectors (MIT et al., 2015), the production can continue. Due to the dependency on the discoursed world market, the quality and efficiency of panels highly differs, just as the availability of many sizes and forms they are produced in. But as the entirety of solar production has massively grown, this does provide for a more democratised market, where a certain form of PV is offered to all people in society. Unique enabling PV products and aesthetically or invisible BIPV becomes a niche for the wealthy, probably produced within the EU by available c-Si technology (TNO, 2023).

Driver 3

To enable the variety of qualitative, second-hand and cheap PV products, the industry supplies a big variety of mounting products. This goes from temporary and low-budget options up to unique and durable products. All products have to compete in a highly cost-price competitive market. Products comply only with the minimal standards and functions.

As an answer to the low-budget demands and installers shortages (JBR et al., 2024), the development of do-it-yourself mounting solutions is evident, as ground mount kits are already offered in 2024. The fourth industrial revolution's 'learnstruments', gamification (Carvalho et al., 2018) and AI support the at home installation and certifying. Integrative mounting and connecting and process optimising show strong potential for cost reduction (Morris et al., 2014).

Besides mounting new panels, from 2030 starts a 'major PV repowering wave in Western EU countries' (ETIP et al., 2021). For whom can afford or needs an upgrade of their individual solar supply, the mounting industry creates products to adapt existing mounting structures for newly top performing panels. This also creates a market for redeveloping and reproducing mounting designs for the older, smaller (Kennedy, 2022) panel sizes. As a result of the scramble for energy, there is also interest for performance enhancing mounting systems, in 2023 already researched with a budget of 0.7 – 1.4 k€/kWp when optimising the azimuth and inclination (Perdigones et al., 2023).

We will also see a significant existence of Energy Management Systems and home-battery solutions to deal with the fluctuation of solar and the grid. Another important factor for this will be 'energy as a service', as companies and producers want to minimise and outsource their risks and stabilise their energy supply. Intelligent data is the key innovation to support these services of the fourth industrial revolution (Carvalho et al., 2018). The government fails in delivering this consistency through the grid, so alternative and local solutions become relevant. There will be risk-competitive and insuring companies providing this service.

Driver 4

The aim for the entirety of solar mounting is on creating the lowest costs, as advised (TKI Urban Energy, 2022). This is implemented by allowing international cost competitiveness and minimising standards and regulation. There will be a high variety of producers of different mounting solutions, being sold in sales, bulk, drop shipping and direct deliveries. Already in 2024, Belgium allowed do-it-yourself installation without a fixed electrical connection, but with power plugs (De Jonge Baas, 2024), which could be seen as democratising the energy transition by creating individual possibilities to fulfill your needs.
Strong customers of solar energy can become local 'prosumers' (Van den Berg, 2018), selling solar energy through sales platforms (Klomp bv, 2023) to others.

Driver 5

Although the European Commission in 2021 introduced the *European Solar Initiative*, the attempt to boost European production had failed, with several producers even going out of business (De Wit, 2024) or moving to another continent (Kurmayer, 2024). According to my interviews with RvO and the solar sector, in 2024, it experiences a lack of consistent priorities to uphold European production and installation.

The dependency for energy on the international market is handled by creating a variable mix of fossils, renewables and nuclear, spreading the dependencies into more manageable risks, but not really boosting any. This leads to what we call the 'scramble for energy'.

For other producers, the direct focus is on domestic production. As the commodity materials for constructions are not so scarce worldwide, limitations on production volume result from production facilities and personnel shortages (MIT et al., 2015).

Driver 6

The development of circular production is limited by the availability of renewable energy and the resulting delayed industries depending on renewable energy, such as green steel. The focus on a strong domestic production industry leads to autocratic distribution of available energy towards the industry. But this also results into strict policies on minimising energy usage and cost reduction. Producers search for available materials in recycling and what is largely available on the international market.

Driver 7

The goal for consumers and government is to minimise their costs and maximise a stable energy supply. As the constructional limitations of a building can be of all sorts (RvO, 2022) and could need configurations, the residential sector also reaches out for practical easier implementable solutions in and around the house. Public and utility solar projects focus on the cheapest mix of solar fields on easy implementable roofs, complemented with available land.

Driver 8

In a more polarised society, under a pressure of rising energy needs and costs, the public acceptance adds a strong dimension to the energy transition (Van Rijnsoever, 2019). Industry and government will increase the public awareness and acceptance through information about energy independency. Landscape and nature disruption will lead to public resistance. Just as singular wealthy consumers will meet resistance, taking land or empty views to fill with their own solar needs.

M4 : Trends matching a Power to People scenario

Driver 1 & 2

The EU decides to rapidly invest in European PV production to build resilience, but too late to create great amounts of supply. Many PV products will still be imported by contracting suppliers and countries in Asia, Africa and South-America. The type and dimensions of PV is depended of the production facilities of contracted parties. The PV produced in the EU will have a focus on domestic and renewable invested (Solarge, 2024), but scalable production. Types as thin-film and perovskites will grow, just as technology in updating existing panels, as thin film and prevoskite production shows easier potential in upscaling European production than cSi (ETIP PV Industry WG et al., 2023) and uses less critical materials. To supply the critical materials needed, countries will focus on urban mining, and to come back from the spilling over 90% of critical materials in 2024 (Rotmans, 2024).

Driver 3
The solar mounting serves the variety of contract produced panels and PV technologies, but aligns one mounting and installation project per batch. This means that a supplied bulk batch of PV panel type X, will be allocated and installed by one public or industry project developer. The individual solar market will only consists of second hand PV, opening up in designs for reusing and relocating solar panels and mounting systems, just as enabling updates, repairs and more efficient/consistent use of the existing individual. After all, 45-65% of PV could potentially be repaired one showing failures, according to ETIP et al. (2022).

TKI Urban Energy (2022) describes the need for circularity in all system components of solar, including the mounting systems. For this, remain, reuse and remanufacturing will be implemented. A set of new products contain of add-ons and efficiency improving products. So besides new produced solar mounting, the industry will offer modular products to convert old and existing structures for other panels or additional products.

Also, in collaboration with EU production of PV, comes the development of climate positive solar mounting, stimulating local biodiversity, sustainability and water management.

Driver 4
From social equality comes the drive for community based solar sharing. As people from within the solar industry started a call for humanising the energy transition (Bloembergen, 2024), emphasize and research grows on local energy communities that embed biodiversity and public participation (Kort & TNO, n.d.). Housing cooperations and ESG driven companies will order solar projects in housing and public services. Solar mounting goes beyond the individual and enables community shared building projects.
As the public energy production and grid availability will have experienced a lack of investment, the government could have to prioritise energy connection to societal functioning buildings, likewise code-blacks scenario's making priotisation frameworks (Acm, 2024).

Driver 5
In the archipelagos scenario, the EU struggles to become energy independent from the international market. Instead of spreading out the energy mix, the main focus of Europe could be as the in 2022 developed REPowerEU-plan; energy saving (Van Hulst, 2022).
Again, to maximise the domestic installation of solar energy, the government will focus on going from split incentive to shared incentive (Verweij S. & Spruit, n.d.), to created greater project based installments ánd be better in control of distribution of energy.
The by the European Commission in 2021 introduced *European Solar Initiative*, will firstly have failed harshly under the price competitive sources of fossils and unrealistic investments, but could eventually find reinvestments and new competitiveness through the policies boosting domestic production. However, the growth of the sector comes late, and can definitely not make up for the loss of production in the early 2020's, going out of business (De Wit, 2024) or moving to another continent (Kurmayer, 2024).

Driver 6
When energy needs rise, the more expansion and efficiency measurements in domestic reach will take place. The production of solar mounting is done by domestic (waste stream) available materials and production. The biggest circular growth in production comes from reusing, recycling and repurposing constructions and constructive materials, as seen with wind turbine blades and the setup for circular construction streams (RvO, 2023).
An important emphasis of production is on the domestic and local job and wealth generation.

Supported by carbon-leakage policies and society, companies become more ESG driven and create shared prosperity through public involvement.

Driver 7
With community solar rises a different view on solar panel locations. Within a district or community, we see the potential roof space as a cumulative total for energy production, fairly distributing the produced energy over all houses, to increase participation and budgeting.
But, communities are also better able to create some off-site space for land fields. And with municipally led community solar programs (EERE, n.d.), it could be strategically located where to install solar to cope with the grid. 'For utilities, developing community solar arrays can lead to improved relationships and engagement with customers' (EERE, n.d.).

As TKI Urban Energy et al. (2021) explain, the ambitioned energy share of solar could be reached without really expanding limits of any specific spatial type. This means that extensive measures or investment for configurations could be left aside.

Driver 8
By humanising the energy transition, it would create more support from society (Bloembergen, 2024). While currently the cost and risk averse behaviour of customers work as a barrier for households to install solar energy (Fatima et al., 2022), a focus on community solar would mean sharing these risks and promoting the choice for solar. Together with a focus on integrating solar with public facilities and nature preservation, solar could become the enabler and booster of societal values and eliminate its visual clash with individual citizens.

Appendix N: Substantiation circularity efforts

Standardised Mass Energy
Remain
As the full focus is on maximising energy production, the build capacity is used as properly as possible. Only single failing panels and some repowering/relocating of solar will result shorter lifetimes.
Reuse
There is no efficiency in reusing compared to removing, recycling and producing into the newest efficient installable version of solar mounting.
Remanufacturing
There is no efficiency in remanufacturing compared to removing, recycling and producing into the newest efficient installable version of solar mounting.
Recycle
As quality and efficiency of the instalment requires the latest innovations, products and configurations, a mass roll-out of solar panels prefers efficient recycling into new products.
Reduce
Reduction is the case for material resources, as for every installed capacity, the systems are optimised on ballast and material costs.
Added climate benefit
The solar mounting systems themselves do not add positive impact to the climate. But making renewable energy mass available, helps certain industries (as steel-production) to become circular as energy is a necessary factor.
Waste based
The product uses recycled or low-carbon new steel from the international market. No specific

(local) waste is inhabited.
Local production
The mass supply of solar mounting systems goes through the international market, but high demand also results in some local production facilities.
Energy efficiency
In this scenario, energy efficiency is a natural effect of the mass efficiency efforts for supply and installation. However, as renewable energy is also highly available, it is not reduced if slowing down production

Circular Energy
Remain
In this pure circular scenario, the maintenance and prolonging of mounting systems always is preferred over other impacting actions.
Reuse
As the product is designed for reuse and redistribution, this is fully the case
Remanufacture
For new configuration in reuse, the product is ready for remanufacturing with (new designed) clamps or altered prefabrication of the components.
Recycle
As the other circular factors are focus points, recycling of the products takes place in smaller sizes. With central facilities it will work, but with material focus on quality, the recycling circumstances because of coatings etc could be suboptimal.
Reduce
Although the product itself is most durable through quality and slightly more material, the solar energy focus is on installing minimal capacity and reducing energy needs. All in all needing less solar mounting systems. Also because reusing eventually phases out new production.
Added climate benefit
Although not specifically focused in the product, the energy strategy for mounting in accessible- and performance-efficient locations, makes room for green and blue roofs.
Waste based
The circular strategy of society is on producing qualitative products, stopping unnecessary waste streams.
Local production
As a true circular supply chain means short and efficient logistics and local handling, production is also spread more locally.
Energy efficiency
The energy efficiency in production itself is not the focus, as producing a qualitative durable product for reuse wins in eventual emission payback time.

Scramble for Energy
Remain
With a focus on mass affordable products, many are of minimal quality or for specific use cases. Remain and prolong is only the case for specific target audiences who are responsible possessors.
Reuse
The scenario actually supports reuse, from a scramble for energy perspective. In scarcity, the individual second-hand market will be active, although not actively designed for. It is just embedded in the DIY simplicity of a product.
Remanufacture

As remanufacturing is an effort of the producer, this will not happen in a scenario where cost-price reduction pushes cheap international production.

Recycle

As this scenario creates lots of waste from failing or disposed products, recycling becomes relevant as cheaper material source

Reduce

The reduction mainly comes from creating P90 products, making cheap products with minimal material costs. Other reduction comes from simple scarcity of PV, not selling more solar mounts than PV is accessible.

Added climate benefit

There is no climate benefit. The focus is on energy security, regardless of the environmental cost

Waste based
There is definitely waste material available in this scenario, although cost-pressing actions minimise the use of these materials. It simply takes more effort than recycling or new resources, so is only applied to substitute scarce materials.
Local production
From geopolitical stances, local production is stimulated, protected or even rescued to secure certain supply.
Energy efficiency
From resource scarcity, energy scarcity in production ánd consumer needs, a focus on minimal energy usage is necessary and probably obligated to maintain supply for society.

Power to People
Remain
In an collective approach, service based models and shared property pushes quality and maintenance.
Reuse
As collective property values the existing products, it helps a focus on reuse of the solar mounting system for new panels or alternative societal projects.
Remanufacture
With solar mounting systems managed on more project sized levels, there is a change for producers to provide remanufacturing as a way of providing reuse of owned-products to a collective.
Recycle
As other circularity focuses are bigger, recycling becomes smaller. However, it still remains an part of the circular strategy.
Reduce
There is less of a focus on reduction, as serving collective energy needs with qualitative products is of more importance. But, sharing does results in less cumulative products in use.
Added climate benefit
The focus of this scenario is on creating maximal societal value, including climate adapting benefits in the solar mounting structure.
Waste based
With an even stronger focus on local wealth and international independency, all resources are valued and stimulated for production. Waste based materials should be maximally used as waste-baste ballast and non-mechanical product materials.
Local production
The use of local production for local wealth and international independency is strongly stimulated via tenders, contracting demands and social paradigms.
Energy efficiency
From resource scarcity and energy scarcity in production and consumer needs, a strong reduction of energy needs is necessary. However, collective actions for energy equality also reduce scarcity and results in more energy usage, although for the correct societal purposes.

Appendix O: Stakeholder Assessment Method

Workshop Future of Solar Energy

11 Juni 13:00 – 16:30

Zetting

Deelnemers:

- Jasper Beekman (R&D Sunbeam)
- Jasper Klein (Projectontwikkelaar klein zakelijk)
- Sander van Osch (groothandel Alius)

Onderzoeksvraag:

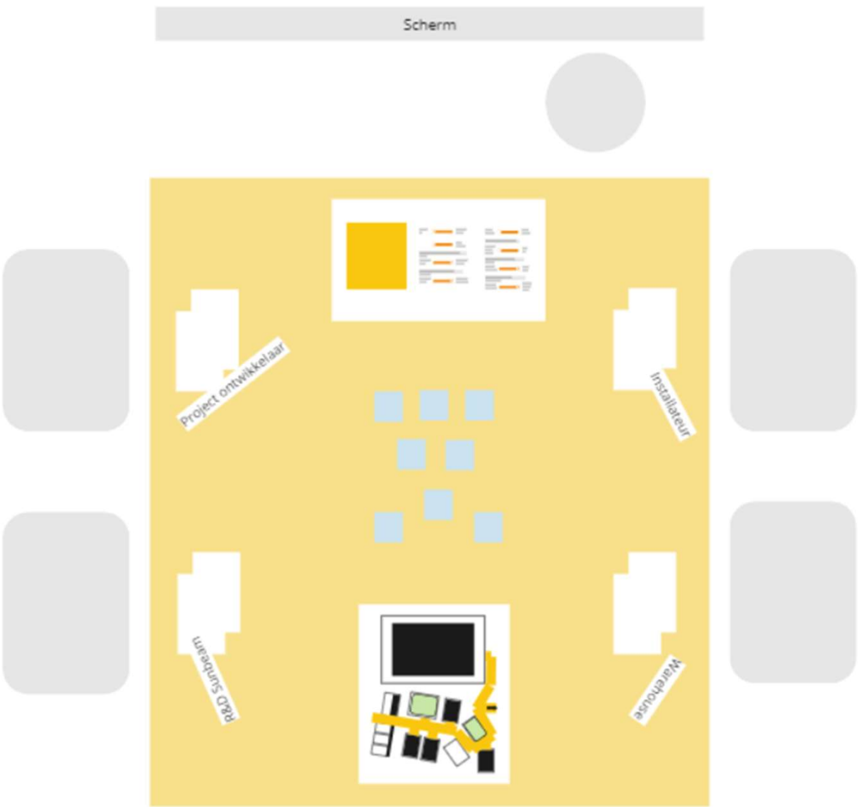
RQ1: Welke belangen voor de toekomstige landelijke energietransitie door zonne-energie spelen er bij de stakeholders uit de zonnepaneel-installatie industrie?

RQ2: Welk mogelijk effect hebben de belangen van de zonnepaneel-installatie industrie op de ontwikkeling van de sector in circulariteit en duurzaamheid?

RQ3: Welke belangen kan een montage-systeem slim beantwoorden om de circulaire ontwikkeling te bevorderen of te versnellen.

Doel: Begrijpen van de belangen die dit industrie-systeem sturen, en welke steunfactoren en belemmeringen een verandering kunnen versnellen of vertragen.

Deelnemers opstelling:



Data verzameling:

Opnames: Zoom H3 recorder

Notities deelnemers: A4 printjes geschreven

Nagestuurde enquête

Data verwerking:
Geschreven data in de templates wordt aangevuld met een analyse van de in discussiefase benoemde belangen, steunfactoren, belemmeringen en benodigde veranderingen.

Uit het terugluisteren van de discussie bij ieder scenario, wordt een affiniteitsdiagram gemaakt. Ieder geleverde inbreng van een participant wordt gelabeld en gecategoriseerd in het diagram.

Vanuit het affiniteitsdiagram en door interpretering van de discussie, zullen relaties tussen de belangen, steunfactoren en belemmeringen deelnemers worden onderzocht.

Planning – Agenda

13:00 Inloop + koffie + voorstel ronde

A. 13:10 Introductie (20 min)
13:10 Project context en Doel van vandaag.
    Scenario constructies, een toelichting
13:20 Individuele doelen
    Preconcepties per deelnemer
    Huidige klimaat / energie transitie visie

B. 13:30 Future Product Scenario's (5 min)
13:30 Introductie key drivers, kaart, tools.

B1 United Mass Solar (35 min)
13:35 Scenario Presentatie + Product
13:45 Invullen template
13:50 Steunfactoren, belemmeringen en belangen toelichten
13:55 Discussie over systeem-invulling van scenario+product
14:10 Einde scenario 1.

Korte PAUZE (5 min)

B2 Circular Energy (35 min)
14:15 Scenario Presentatie + Product
14:25 Invullen template
14:30 Steunfactoren, belemmeringen en belangen toelichten
14:35 Discussie over systeem-invulling van scenario+product
14:50 Einde scenario 2.

Goede PAUZE (15 min)

B3 Scramble for Energy (35 min)
15:05 Scenario Presentatie + Product
15:15 Invullen template
15:20 Steunfactoren, belemmeringen en belangen toelichten
15:25 Discussie over systeem-invulling van scenario+product
15:40 Einde scenario 3.

Korte PAUZE (5 min)

B3 Power tot he People (35 min)
15:45 Scenario Presentatie + Product
15:55 Invullen template
16:00 Steunfactoren, belemmeringen en belangen toelichten
16:05 Discussie over systeem-invulling van scenario+product
16:20 Einde scenario 4.

C. Afronding (10 min)
16:20 Scenario wenselijkheid en haalbaarheid
16:25 Samenwerken & system change

A: Introductie

A1 Project context en doel
<u>*Waarom scenario's:*</u>

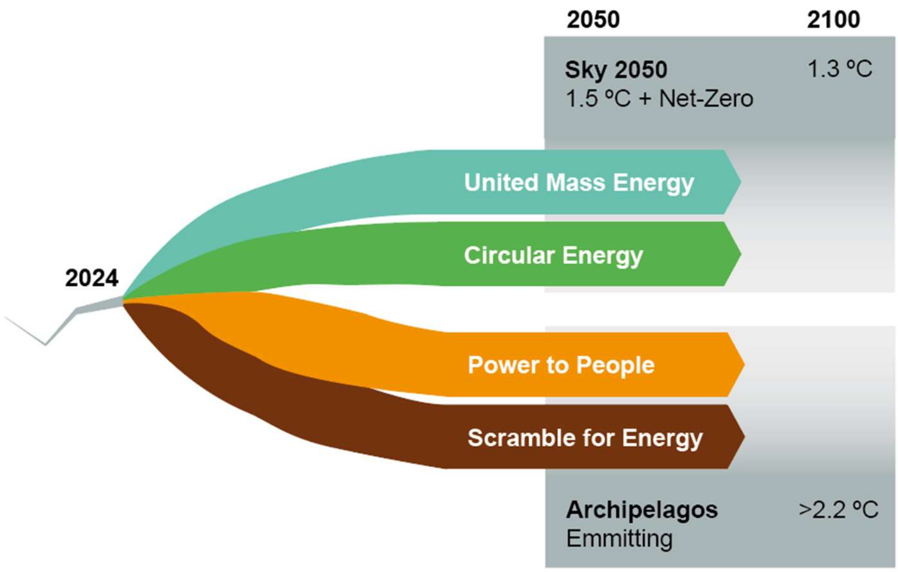
- *Solar: Verschillende business-contexten in sterk alternatieve toekomsten mogelijk:*
  -> het kan nog veel kanten op.
- *Alhoewel gestuurd door trends en ontwikkeling, liggen verassingen op de loer*
  -> overheidsbeleid, markt en internationale levering
- *Voor managers: afstappen van persoonlijke 'meest waarschijnlijke toekomst'*
  -> blik verwijden: geen wensdenken maar ook geen korte-termijn realisme

Waarom scenario's in product en business ontwikkeling:

- *Voorbereid hoe je business & product in een toekomstige context ingevuld kan worden*
- *Dit helpt de vertaling naar ontwikkeling, investering en besluitvorming*

Bovenal, een toekomstscenario overkomt je niet alleen, maar stuur je zelf ook. Door deze methode van product-scenario's leer je welke bedrijfskeuzes een bijdrage leveren aan de verandering richting een zeker scenario.

Construering scenarios:
Twee Shell scenarios
Future forward approach -> 4 scenarios



A2 Verwachtingen en Preconcepties
Verwachtingen
Wat zijn je verwachtingen voor vanmiddag? Wat hoop je te ontdekken/bijdragen?

Preconcepties
Als je nu zelf een toekomstbeeld zou moeten schetsen voor de zonne-energie sector, hoe ziet die er dan uit?
- Denk aan paneel types, installatie-methodes, businessmodellen, type product en klanten.

B: Discussie over systeem-invulling scenario+product

Vragen om op te sturen, afhankelijk van bespeurde relevantie van de onderwerpen in de discussie.

Invloed

- Invloed van dit scenario op de eigen bedrijfsvoering / de industrie
- Invloed van de industrie / eigen bedrijfsvoering op de verwezenlijking van dit scenario

Belang

- Wie heeft er belang bij dit scenario? En wie niet?
- Hoe zwaar wegen bepaalde belangen?

Consument & Prijs

- Wie is de consument in dit scenario, en met welk aanbod en concurrentie wordt de consument gewonnen?
- Welke omstandigheden bepalen de prijs-waarde en welke de kosten?
- Welk consumentengedrag past bij dit scenario? En hoe wordt dat gedrag gestimuleerd?

Businessmodel / services

- Welke (nieuwe) rol zou jouw bedrijf uitvoeren in deze context?
- Moet er voor dit scenario iets veranderen in de value chain van de solar industrie?
- Hoe kijk je aan tegen de rol in de End of Life in het scenario?

Product

- Wat moet het installatieproduct (en zonnepaneel) bieden voor u om in dit scenario te werken?

WEL discussiëren over:

- Haalbaarheid van eigen werkzaamheden/bedrijfsvoering. Dit geeft immers uitdagingen in de veranderingen bloot. (Maar NIET haalbaarheid door externe politiek, recente ontwikkelingen)
- Afhankelijkheden onderling. Wat heb jij als bedrijf X nodig van bedrijf Y om dit scenario werkbaar te maken?
- 2040: Op welke manier men verwacht dat samenwerkingen veranderen op de lange termijn

NIET discussiëren over:

- Geopolitieke redenen voor het scenario buiten de eigen industrie / energie-sector.
- Is het scenario wenselijk? Dit bespreken we later, we moeten het scenario eerst verder ontdekken voordat we deze conclusie trekken.
- Realisme van de externe/mondiale veranderingen die het scenario voeden.

- Korte termijn: Geen korte termijn markt-effecten (alleen lange termijn), geen korte termijn samenwerkingen / deals

C: Samenwerking en toekomst

Template

Vul de template in ‘Wenselijk en haalbaar’

Optioneel: Conclusiegesprek Samenwerking

- In welk scenario kunnen jullie elkaar vinden?
- In wat voor industrie focus voor dat scenario kunnen jullie elkaar vinden?
- Helpt een scenario-sessie als deze bij het geven van richting aan je bedrijfsvoering?

Template Scenario's impact Scenario: .... Van: ....

In hoeverre sluit dit scenario aan op de huidige **belangen** van jouw bedrijfsgroep?	geen belang 1 2 3 4 5 6 7 veel belang
Steunfactoren: Welke aspecten in je bedrijfsvoering zie je (ontwikkelen), die de totstandkoming van dit scenario kunnen ondersteunen? *Denk aan: diensten, klant/markt, logistieke inrichting, product, prijs, technologie*	
Belemmeringen: Welke aspecten in je bedrijfsvoering zie je (ontwikkelen), die de totstandkoming van dit scenario kunnen belemmeren? *Denk aan: diensten, klant/markt, logistieke inrichting, product, prijs, technologie*	
Veranderingen: Welke veranderingen en ontwikkelingen acht je nodig om in dit scenario je bedrijfsvoering te doen? *Denk aan: samenwerkingen, wetten, investeringen, afhankelijkheden*	

C: Wenselijk en haalbaar Van:

Scenario	**Circular Energy**	**Standardised Mass Energy**	**Scramble for Energy**	**Power to People**
Wenselijk voor uw bedrijf	failliet succes 1 2 3 4 5 6 7	failliet succes 1 2 3 4 5 6 7	failliet succes 1 2 3 4 5 6 7	failliet succes 1 2 3 4 5 6 7
Inspanning voor haalbaarheid	stabiel herziening 1 2 3 4 5 6 7	stabiel herziening 1 2 3 4 5 6 7	stabiel herziening 1 2 3 4 5 6 7	stabiel herziening 1 2 3 4 5 6 7
Ontwikkelfocus bedrijf: Denk aan verandering van: businessmodel, product, diensten, partners…				
Ontwikkelfocus industrie: Denk aan verandering van: klanten, producten, proposities, imago, beleid				

Appendix P: Results of the Stakeholder Assessment

In the excel file 'Stakeholder Assessment Notes – Affinity Diagram – 2024 - TU Delft IPD' you can find the results of the Stakeholder Assessment as conducted in Appendix I.

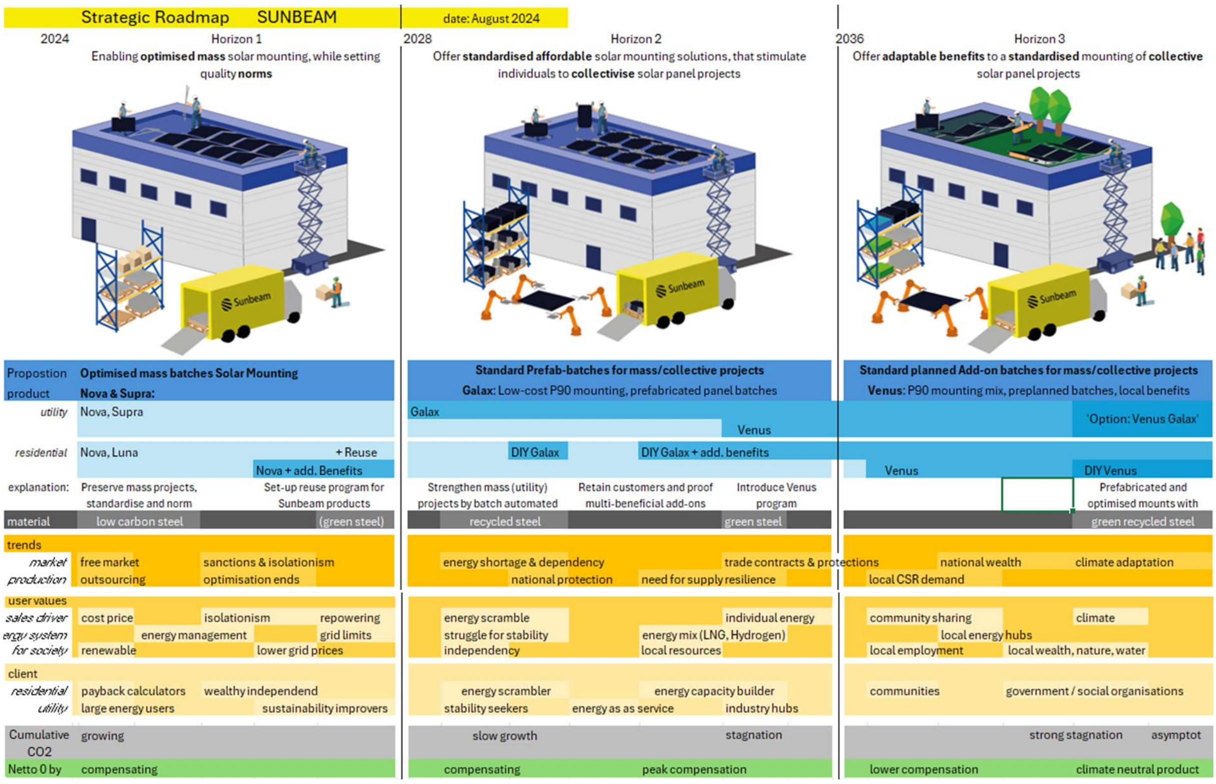
The first sheet 'Affinity Diagram' both shows the written input from respondents on support, obstruct and change per scenario, as well as the transcribed remarks picked up in the group discussion afterwards. For all written input, I categorised the separated data into the topic of interest with the best affinity to it. This categorisation is used in the second sheet.

The second sheet 'Topic Affinity Count' is used to count the topic affinity per scenario and respondent. This is used to gain insights in the relative consideration of certain interests for a responding stakeholder.

Appendix Q: Roadmap for Sunbeam

In the excel file 'Strategic and Tactical Roadmap for Sunbeam - Solar Mounting Product Scenarios - 2024 - TU Delft IPD' you can find the developed Strategic and Tactical roadmap developed for Sunbeam.

This is an example of only the Strategic roadmap in Excel:



Appendix R: Approved Project Brief

TU Delft

DESIGN FOR our future

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME
Complete all fields and indicate which master(s) you are in

Family name [redacted]
Initials
Given name
Student number

SUPERVISORY TEAM
Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Conny Bakker	dept./section	Sustainable Design Engineering
mentor	Thomas van Arkel	dept./section	HCD/DA
2nd mentor	Jasper Beekmann		
client:	Sunbeam		
city:	Amersfoort	country:	Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in by the Chair of the supervisory team

Sign for approval (Chair)

Conny Bakker
Digitally signed by Conny Bakker
Date: 2024.02.22 10:45:52 +01'00'

Name Conny Bakker   Date 22 Feb 2024   Signature

CHECK ON STUDY PROGRESS

To be filled in by SSC E&SA (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total ______ EC

Of which, taking conditional requirements into account, can be part of the exam programme ______ EC

★	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Robin den Braber — Digitaal ondertekend door Robin den Braber Datum: 2024.03.13 12:23:54 +01'00'

Name Robin den Braber Date 13 mrt 2024 Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	★	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

★	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique von Morgen — Digitally signed by Monique von Morgen Date: 2024.03.14 09:28:32 +01'00'

Name Monique von Morgen Date 14 Mar 2024 Signature

[redacted]

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Future product-scenario's for sustainable solar mounting systems

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The solar mounting industry is an important driver for the energy transition. The industry is responsible for delivering stands, clamps and feet for attaching solar panels to flat and pitched roofs and floors. For this industry, it is even more important to lead on sustainable transitions towards a climate neutral product, as its sustainability level should match the product it serves. Clients and investors search and demand for the most climate beneficial set-up for their solar power, including the environmental effect of the solar-mounting products.
At the same time, the product should benefit efficient mounting procedures for installers and should perform durable and safely in an outside environment. The actual solar panel is the greater investment and adds positive environmental impact, and should therefore always be served properly.
Current solar mounting systems consist heavily out of high eco-impact steel and a variety of materials. A challenge the industry is facing is how to replace or improve these materials, without limiting the mounting environments and scaling of solar panel placement. The current product designs are being optimised, but the potential paths towards a climate neutral mounting-system in 2040 are absent.
Looking at figure 1, the challenge for a company is in entering and investing in the rightfull product path, that will lead to an eventual zero-carbon product. Right now, the design investment in uncertain alternatives feels mostly random. Without any proof of concept, the designers time-investment in developing and implementing elements/technology/ research that could lead to possible alternatives is risky and is therefore often not happening.
In my hypothesis, I think that a physical design of the eventual product-concept, in a way that it is fitting the wider system it would have to eventually work in, can give great insights in the desirability, viability and feasibility of that alternative product path. This should A) help eliminating unrealistic and useless product-paths and B) help setting up a roadmap and funnels for what actions and factors should become, in order to potentially realise the alternative product.

→ space available for images / figures on next page

introduction (continued): space for images

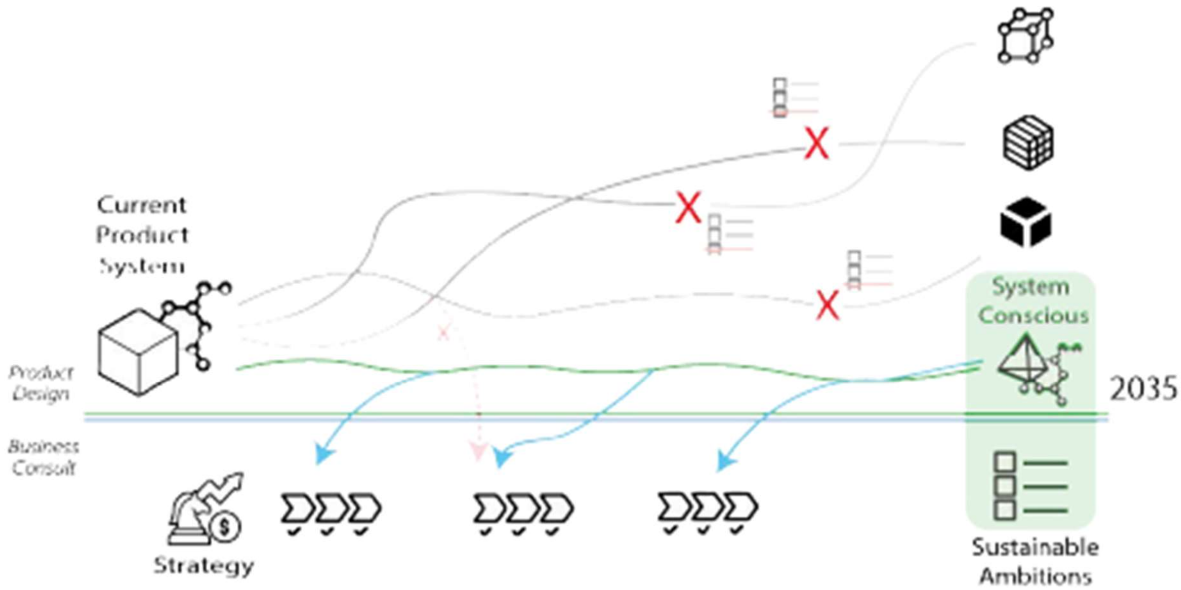


image / figure 1 Future System Conscious design, and how it could inspire system shifting strategies.

image / figure 2

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The company Sunbeam is looking for suggestive and alternative product designs of their solar-mounting system for flat roofs, that show potential in climate-neutral materials and production in 2040. Up to now, the company did some exploration on a few simple intuitively chosen alternatives: reusing wooden beams or using low-quality recycled plastics. But there is no deliberate research or exploration of the broad production possibilities and market needs in an `climate neutral solar mounting system' that is aimed for.

A proper product design exploration of alternative mounting systems and an outline of the desirability, feasibility and viability could help R&D and Strategic management to choose from potential future pathways. Exploring these future pathways via physical embodiment designs of the potential future product, should be able to make strategic and realistic decisions more tangible.
Eventually, the more promising future product-scenario's should lead to the creation of one or several tactical roadmaps that guide the research and development of the flat-roof mounting system. When having a concrete design for each potential path-way, the uncertainties, funnels and research to reach such an outcome should become clearer.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design future-product-scenario's for a climate neutral solar-mounting system on flat-roofs and create tactical roadmaps for product development of these concepts.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

This project is a design-project on the future product and production scenario's for flat-roof solar mounting systems ('Nova') for the company Sunbeam. I will design potential redesigns for a climate neutral `Nova' in 2040 from the following (sustainable) design strategies: Ecodesign and LCA, Cradle2Cradle, Business Model Innovation and trend and technology research as DEPEST and Creative Trend Research. From research with the production partners and clients and these design strategies, I will create:
A) Future Program of trends, developments and needs in production and clients of the solar industry.
B) Future product-scenario's and redesigns of Sunbeam's flat-roof solar-mounting system `Nova' for climate neutral 2040.
C) Assessing the viability, feasibility and desirability of the product scenario's with clients, producers and the product management of Sunbeam.
D) Iterate on the final potential product-scenario's and create corresponding implementation/tactical roadmap that includes the steps in understanding challenges and funnels on design, development, investment and business.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting, mid-term evaluation meeting, green light meeting*** *and* ***graduation ceremony****. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	16 feb 2024
Mid-term evaluation	7 mei 2024
Green light meeting	11 juli 2024
Graduation ceremony	22 aug 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

From being an IPD student, in Advanced Concept Design, I experienced the potentials and limits of embodiment concept design in reaching sustainable transitions. I found that physical designs are not only usefull in delivering explicit products from product briefs, but can also help provoke conversations and bring insights on strategic level of product management.

Besides the actual design and development of these future product-scenario's and the roadmaps, I want to conduct a small performance study and reflection on the effectiveness of such `future product-scenario's'. I want to study how these concrete Vision Concepts help judge desirability, viability and feasibility of potential pathways, and what such a physical product design can bring in the creation of strategic tactical roadmaps. This research will be performed in the form of an retrospective survey/interview with the subjects of actions C.