

Solar Sync Stadium

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Sources of Innovation

Group 2

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Introduction

The purpose of this project is to design an integrated photovoltaic (PV) system that incorporates free-space luminescent solar concentrators (FSLSCs). These concentrators are intended to redirect sunlight from surfaces that would otherwise contribute minimally to energy production, thereby enhancing the efficiency of commercial solar panels. The objective is to develop a system optimized for energy capture in a stadium setting, balancing practicality with innovative design principles rooted in optics and photovoltaics.

Our approach is structured into three key phases: *Introduction*, *Concept Building*, and *Finalizing*. Each phase utilizes two models to address specific design challenges and progressively refine the solution. Through this project, we explore how solar energy generation can be effectively integrated into the specific context of the “Grolsch Veste” stadium situated in Enschede.

Problem Analysis

The primary objective of this project was to design an innovative solution using Free Space Luminescent Solar Concentrators (FSLSCs) to generate sustainable energy effectively. Initially, we explored several potential environments, including greenhouses, facades, and transportation hubs. Stadiums, however, emerged as the ideal choice due to their extensive unused surface areas, high energy demands, and compatibility with FSLSCs. Stadiums consume significant energy during events, creating an excellent opportunity to offset this with photovoltaic solutions. Additionally, many stadiums have structures that readily support solar installations without extensive modifications.

After selecting stadiums as the main focus, we chose the Grolsch Veste Stadium in Enschede for our case study. Located nearby, this choice provided the practical advantage of direct access, allowing us to observe and visualize the structure in person and apply our design concept in a real-world environment.

For our innovation approach, we adopted an iterative and reflective process, selecting tools progressively. We began with the Delft Innovation Model as a foundational framework, grounding the project in a structured innovation approach. Next, we introduced TRIZ to address technical constraints related to structural integration and environmental compatibility. Each method's effectiveness was evaluated in real-time, informing the selection of subsequent tools. This led us to choose Platform-Driven Product Development for scalability, the Risk Diagnosing Methodology to prioritize project risks, Constructive Technology Assessment to address social and environmental dimensions, and Innovation Design & Styling to balance function with aesthetics.

Our dynamic, iterative selection allowed us to adapt our approach as the project evolved, aligning each method's strengths with our project's shifting needs. In the sections that follow, we detail how each tool was applied within our case study, demonstrating how they collectively refined our conceptual design for sustainable energy integration in stadiums.

Methodology

We organized our project into three phases: the Introductory Phase, Concept Building Phase, and Finalization Phase. In each phase, we combined two innovation tools—one focused on principle optimization and the other on form and layout—allowing us to address both technical and visual aspects simultaneously. This approach fostered cohesive development in both functional and aesthetic elements of our design.

In the *Introductory Phase*, we applied the Delft Innovation Model first, followed by TRIZ, establishing the conceptual foundations. These tools helped us clarify our design objectives and address technical challenges in a structured manner. Moving into the *Concept Building Phase*, we implemented Platform-Driven Product Development (PDPD) and the Risk Diagnosing Methodology (RDM). This phase brought significant design evolution, as we integrated the outcomes of these models into our concept, refining scalability and risk prioritization. Finally, in the *Finalization Phase*, we used Constructive Technology Assessment (CTA) and Innovation Design & Styling models. This phase provided an overarching view of our design's progress and demonstrated how each model informed the final outcome.

Each phase concluded with a brief analysis, summarizing the insights and transformations achieved through each tool, showcasing the progressive refinement of our sustainable energy concept for stadium integration.

Introductory Phase

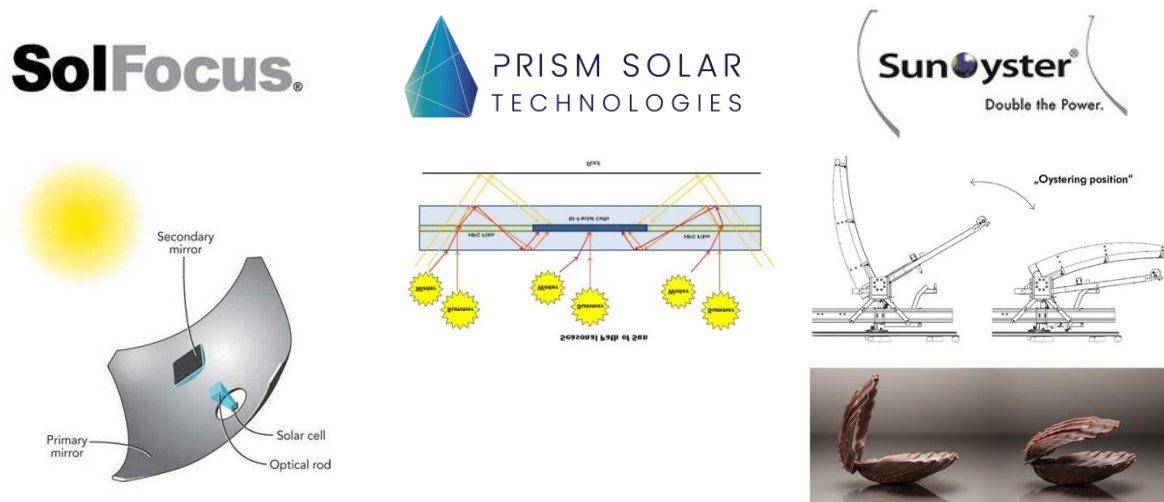
Delft Innovation Model

We selected the Delft Innovation Model (DIM) as our starting tool, given its structured approach to managing the complex innovation process at Grolsch Veste Stadium. DIM divides the project into clear phases that align with our technical objectives and stakeholder needs. These key phases—Strategy Formulation and Design Brief—enable us to transition from defining project goals to establishing specific design requirements (Reinders Angele et al., 2013).

Strategy Formulation

During the Strategy Formulation phase, we established our objectives, identified key stakeholders, and conducted a SWOT analysis. This analysis illuminated the stadium's energy needs and operational requirements, highlighting the potential of FSLSCs to optimize energy capture on its underutilized surfaces. The stadium management's commitment to sustainability further strengthened our focus on renewable energy solutions.

On the external side, we investigated trends in solar technology, focusing on solar concentrators and Building-Integrated Photovoltaics (BIPV). We drew insights from successful solar integrations at venues like Amsterdam ArenA (Warmerdam et al., 2020) and Mercedes-Benz Stadium (Hannah Solar, 2017). Additionally, competitor analysis of companies such as Prism Solar (Prism Solar, 2024) confirmed the feasibility and competitive edge of our approach within the sports sector. This comprehensive analysis grounded our design strategy, ensuring alignment with technical and sustainability goals.



Above, an overview is provided of competitors and their design approaches in the solar energy sector, highlighting their unique features and innovations (Petrov L., 2011; SunOyster, 2024).

In the Strategy Formulation phase, we recognized the importance of aligning our FSLSC-PV project at Grolsch Veste Stadium with both technical and societal objectives by understanding stakeholder interests and influence. We employed a power-interest matrix to categorize stakeholders into primary, secondary, and tertiary groups based on their influence (power) and concern (interest) regarding the project.

Primary Stakeholders have high power and high interest, significantly influencing our project's financial, operational, and regulatory dimensions. This group includes:

- **Stadium Owners and Management:** They hold the highest influence due to their control over budget allocation, implementation decisions, and alignment with the stadium's environmental goals. Their priorities include operational efficiency, cost savings, and maintaining a sustainable public image.
- **Local Government and Municipal Authorities:** They are essential for regulatory approvals and funding support, possessing the power to provide permits and potential incentives. Their interest lies in achieving regional renewable energy and environmental goals.

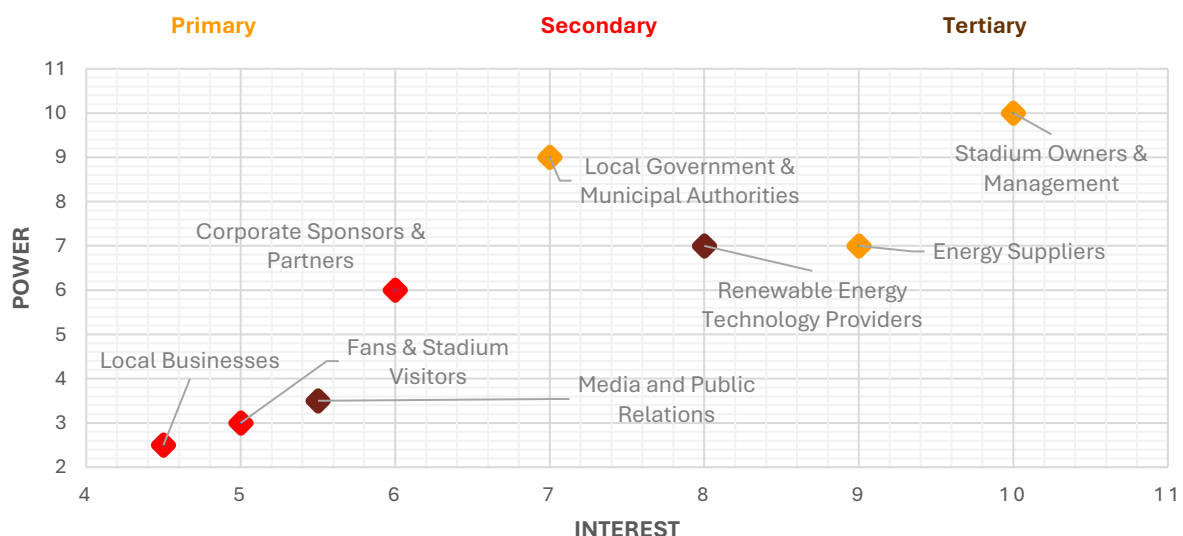
- **Energy Suppliers:** While they have medium power relative to decision-making, their high interest stems from ensuring the system's technical compatibility and profitability, especially regarding power purchase agreements (PPAs) for surplus energy.

Secondary Stakeholders exhibit medium power but high interest, as their engagement affects public perception and community support. This group includes:

- **Fans and Stadium Visitors:** They possess low power yet show high interest in the project's environmental impact, which can shape its public image and social acceptance.
- **Corporate Sponsors and Partners:** With moderate power, they provide financial support and seek alignment with eco-friendly initiatives for marketing and branding opportunities.
- **Local Businesses:** They have low power but a medium interest in the project's success, as it can enhance local economic activity and community pride.

Tertiary Stakeholders generally have lower power and interest but provide valuable support through technical expertise and advocacy. This group includes:

- **Renewable Energy Technology Providers:** They possess medium power and interest, being critical for supplying FSLSC and PV technology, which influences system integration and maintenance.
- **Environmental Organizations:** Though they have low power, their medium interest in advancing renewable energy and environmental stewardship makes them important endorsers of our project.
- **Media and Public Relations:** They hold low power but have a medium interest in communicating the project's environmental benefits, which can significantly impact its social acceptance.



The power-interest matrix overview above serves as a strategic guide for stakeholder engagement in our project’s next steps. By employing this structured analysis, we prioritize our approach: we actively involve primary stakeholders—stadium owners and local authorities—in critical decision-making processes, while engaging secondary stakeholders, such as fans and sponsors, to foster public support. Meanwhile, tertiary stakeholders, including technology providers and media representatives, contribute valuable advocacy, technical insight, and outreach efforts. This comprehensive approach ensures the FSLSC-PV system is developed with full awareness of its organizational, social, and environmental context.

In the next step, we synthesized our findings from the internal and external evaluations in the SWOT analysis to clarify the project’s strengths, weaknesses, opportunities, and threats. Our strengths include the unique capability of FSLSCs to capture light from non-ideal angles and the stadium’s commitment to environmental sustainability. Weaknesses encompass energy loss due to light redirection and potential maintenance challenges for large-scale installations exposed to the elements. Opportunities lie in gaining positive publicity, scalability, and alignment with increasing environmental standards, while threats consist of regulatory hurdles, rapid technological changes, and the risk of obsolescence. The full SWOT breakdown is detailed below.

STRENGTHS	• Utilization of otherwise inefficient vertical surfaces • Improved light capture from non-ideal angles • Aesthetic integration with stadium architecture • Reduced heat load on stadium materials
WEAKNESSES	• Energy loss during light redirection (30-50%) • Dependency on material quality (susceptible to degradation) • High maintenance and durability concerns, especially in harsh environments
OPPORTUNITIES	• Positive publicity for sustainability initiatives • Potential for scalability and future expansion to other venues • Reduced energy costs and environmental impact
THREATS	• Rapid advancements in solar technology could outdate the system • Exposure to harsh weather conditions may lead to degradation • Regulatory and permitting challenges for architectural modifications

We identified several strategic focus areas for further exploration in the design phase:

- **Architectural Integration:** Ensuring FSLSCs blend seamlessly with the stadium's design to maintain aesthetic appeal.
- **Maximizing FSLSC Efficiency:** Optimizing configurations to enhance energy capture while preserving durability.
- **Durability and Maintenance:** Choosing materials and designing systems that withstand environmental exposure to minimize maintenance needs.
- **Regulatory Compliance:** Collaborating closely with local authorities to address zoning, environmental, and safety regulations impacting the project.

Design Brief Formulation

In the Design Brief phase, we transformed the strategic insights from the Strategy Formulation into targeted design objectives, technical specifications, and clear parameters for the FSLSC-PV system. This phase shapes the system's configuration by optimizing the arrangement of FSLSCs on underutilized surfaces to capture and redirect light onto horizontally mounted PV panels, maximizing energy output within the stadium's structural constraints. Our technical guidelines also address placement angles, energy conversion needs, and grid integration, with modularity prioritized to allow for straightforward maintenance and upgrades.

Given the stadium's high-profile nature, attention to aesthetic and architectural details is essential. FSLSCs with customizable colours and finishes are designed to integrate seamlessly into the stadium facade, enhancing its eco-friendly image without disrupting its visual appeal. Drawing from successful solar integration projects at other stadiums, our approach balances functionality with visual cohesion.

Sustainability and stakeholder feedback are central to the brief, reflecting both the stadium's renewable energy goals and the community's expectations. FSLSC technology reduces reliance on non-renewable sources, lowering the stadium's carbon footprint and operational costs. Input from stakeholders, such as local authorities and environmental groups, has refined our focus on minimizing maintenance and meeting public environmental standards, ensuring that the FSLSC-PV system aligns with both regulatory standards and local sustainability goals.

TRIZ

In our TRIZ analysis, we began by identifying several contradictions that could impact the FSLSC-PV project. These contradictions include:

- Light Capture Efficiency versus Aesthetic Integration
- Cost versus Energy Efficiency
- Maintenance Ease versus Integration
- Technical Complexity versus Ease of Installation
- Size of FSLSCs (Efficiency) versus Installation Space

We also noted contradictions such as Performance Monitoring versus System Complexity, Seasonal Performance versus Aesthetic Appeal, System Scalability versus Specialization to Grolsch Veste, Environmental Impact versus Material Selection, and Reliability versus Innovation.

Given the time constraints of our project, we categorized these contradictions into two groups based on their importance. The high-importance contradictions were prioritized due to their direct influence on the project's success and stakeholder satisfaction. These include Light Capture Efficiency versus Aesthetic Integration, Cost versus Energy Efficiency, Maintenance Ease versus Integration, Technical Complexity versus Ease of Installation, and Size of FSLSCs (Efficiency) versus Installation Space (Altshuller Genrikh et al., 1997). Below, you can see the high-importance contradictions along with their corresponding principles.

Light Capture Efficiency vs. Aesthetic Integration	• Principle #32 – Changing the Colour • Principle #1 – Segmentation • Principle #6 – Universality
Weight vs. Structural Integrity	• Principle #4 – Asymmetry • Principle #29 – Pneumatics or Hydraulics • Principle #2 – Taking Out
Cost vs. Energy Efficiency	• Principle #10 – Prior Action • Principle #35 – Parameter Changes • Principle #26 – Copying
Maintenance Ease vs. Integration	• Principle #15 – Dynamics • Principle #13 – The Other Way Round • Principle #7 – Nested Doll
Technical Complexity vs. Installation	• Principle #10 – Prior Action • Principle #2 – Taking Out • Principle #24 – Intermediary
Size of FSLSCs (Efficiency) vs. Installation Space	• Principle #3 – Local Quality • Principle #17 – Another Dimension • Principle #30 – Flexible Shells and Thin Films

The low-importance contradictions, while still relevant, are noted for consideration later, including Performance Monitoring versus System Complexity, Seasonal Performance versus Aesthetic Appeal, System Scalability versus Specialization to Grolsch Veste, Environmental Impact versus Material Selection, and Reliability versus Innovation. This categorization helps us focus our efforts on resolving the most critical challenges facing our project.

To effectively address the identified high-importance contradictions, we prioritize the following principles with their possible implementation in our design approach:

- **Segmentation (#1)** emphasizes a modular design, which is crucial for ease of installation, customization, and scalability.
- **Composite Materials (#40)** focuses on using lightweight yet strong materials, ensuring that the system remains efficient without overloading the stadium's structure.
- **Dynamics (#15)** highlights the importance of incorporating adjustable panels and dynamic features to enhance both performance and aesthetics.
- **Changing Colour (#32)** underscores the significance of aesthetic appeal, especially in high-visibility stadium projects, where the system must look impressive while functioning effectively.
- **Prior Action (#10)** advocates for pre-assembled parts and standardized components, which simplify installation and help reduce costs.

By implementing these principles, we create a design that balances functionality with visual integration at Grolsch Veste Stadium.

We envision our concept for the FSLSC-PV system at Grolsch Veste Stadium as a visually dynamic and modern structure that seamlessly integrates with the existing architecture. The design features angled and curved FSLSCs installed on both vertical and horizontal surfaces to optimize energy generation and provide shading for spectators. These modular, lightweight panels include colour-changing properties, enhancing aesthetic appeal while maintaining energy efficiency.

On the roof, we plan to install large FSLSC panels at optimal angles to capture sunlight effectively. Some panels will be photochromic, adjusting their colour based on sunlight intensity, while others will utilize flexible thin-film solar technology to adapt to the stadium's curves. For the facade, vertical FSLSCs will be placed along glass walls, using thin, lightweight materials that allow unobstructed views while contributing to energy generation. Transparent solar panels will help maintain the stadium's visual integrity.

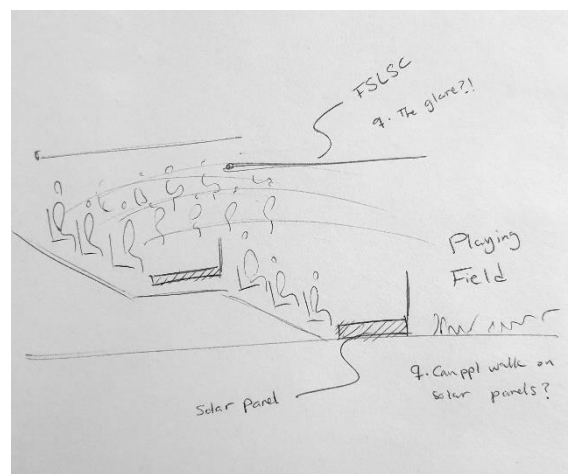
Additionally, we incorporate smaller, flexible FSLSCs into shading structures over seating areas, designed to be self-cleaning and adjustable, serving both energy collection and shading or acoustic barrier functions. Throughout our design, modularity remains a key focus, enabling easy replacement, repair, or upgrades of components as needed. This comprehensive approach ensures that our FSLSC-PV system meets functional, aesthetic, and environmental goals for the stadium project.

Conceptual Foundations

The generated concepts for adding solar panels and FSLSCs to stadiums explore different ways to utilize unused surfaces, optimize placement angles, and design modular components for easier maintenance. We also consider how colour choices can integrate panels with the stadium's aesthetics and how some elements might serve multiple purposes. These ideas aim to enhance energy production efficiency, practicality, and visual harmony with the stadium.

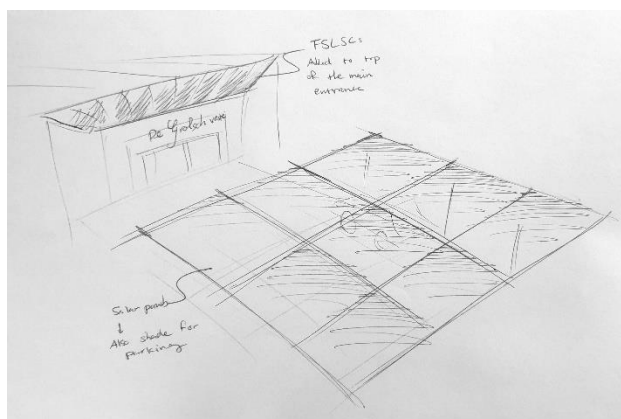
Concept 1: Grandstand

The first concept integrates solar design elements into the seating area to provide shading for spectators. This concept proposes using bifacial solar panels as vertical sheets behind the seats, capturing sunlight from both sides, while incorporating FSLSCs to create shading above each row. This configuration not only enhances comfort for viewers but also contributes to energy generation, integrating functionality with the spectators' experience in the stadium.



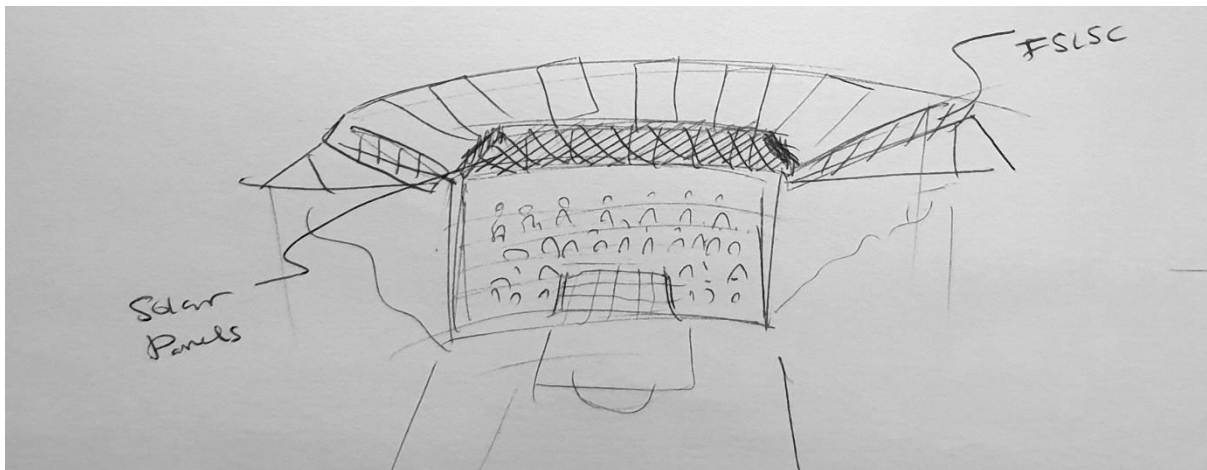
Concept 2: Parking Shade

In the second concept, the FSLSC would be situated on the southwest side of the stadium, reflecting light towards the parking lot. This lot would feature a shading structure provided by solar panels that

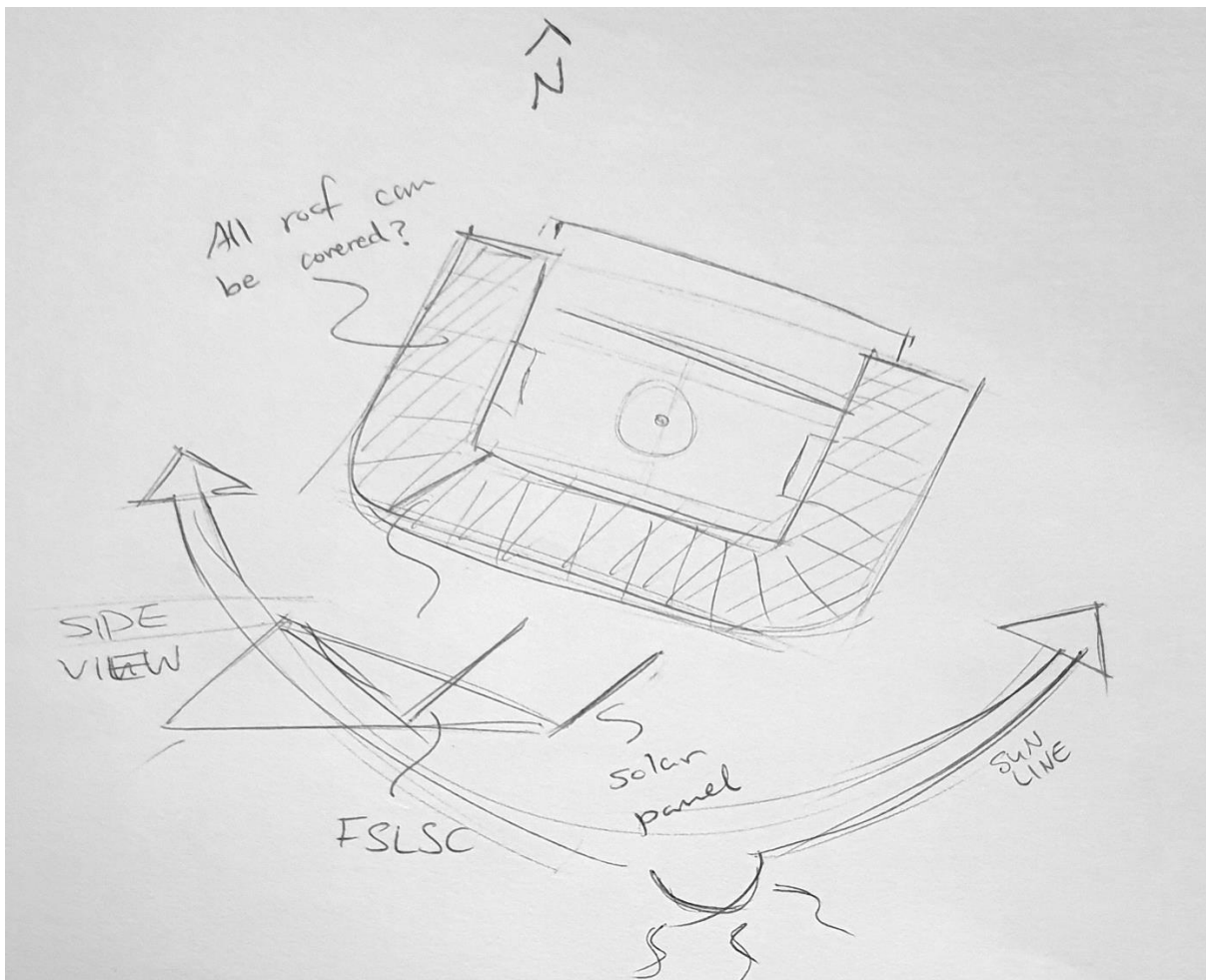


receive light from the stadium's FSLSC. This concept facilitates shading for parked cars while generating energy. However, the distance between the FSLSC and the solar panels is relatively large, and the panels are angled northeast, which would result in low energy generation values.

Concept 3: Roof



The third concept involves placing solar panels and FSLSCs on the stadium roof. This configuration could provide shading inside the stadium while maintaining a low visual profile from ground level. This setup is more ideal considering the angling of the solar panels compared to the second concept. Different positions for the solar panels on the roof would result in varying stresses, which has been an issue in the past for the Grolsch Veste, so we should consider various placements and configurations.



Concept Building Phase

Platform Driven Product Development

Informed by insights from our previous innovation models, we implemented the Platform-Driven Product Development (PDPD) approach to develop a modular, adaptable solar energy solution for Grolsch Veste Stadium. This method allows our FSLSC-PV system to be applied in a wide variety of settings, supporting scalability and customization to meet unique architectural needs. PDPD's emphasis on modularity enhances risk management by standardizing components, which we can then customize for different markets. Our PDPD strategy involves defining the core platform, establishing a modular architecture, creating product families, managing product variability, and expanding into markets beyond stadiums.

Platform Definition and Core Technology Integration

At the heart of our PDPD strategy for the Grolsch Veste project is the development of a flexible, modular platform. This platform organizes the FSLSC-PV system into core components, each designed to fulfil a specific role:

- FSLSCs to capture and redirect light on vertical surfaces,
- PV Panels to convert this light into electricity,
- Mounting Systems, Inverters, and Cabling to ensure stability, energy conversion, and grid compatibility, and
- Energy Monitoring Systems for performance tracking and integration with broader energy management systems.

Through this organized, modular approach, we can adapt our platform for various architectural and functional requirements. FSLSCs and PV panels can be resized and configured to achieve goals like maximizing energy capture or minimizing visual impact. By defining core technology in this adaptable way, we facilitate repairs and upgrades, ensuring that our system remains suitable for various applications, reinforcing PDPD's adaptability for infrastructure-based solar solutions.

Modular Architecture and Scalability

Our PDPD framework supports a modular architecture essential for scaling the Grolsch Veste FSLSC-PV system across different energy demands and building constraints. This flexibility means that we can scale module groups down for smaller facilities or expand them for large venues like stadiums. A modular structure simplifies not only installation but also maintenance and upgrades, as we can replace individual components like FSLSCs or inverters independently, minimizing disruption. Standardized core components reduce production costs, making our system feasible for a range of budgets while allowing customization to fit specific architectural needs.

Product Families and Customization for Market Segments

Leveraging PDPD, we developed distinct product families for the FSLSC-PV system, each tailored to different markets. Each family retains the core platform while adapting features to the functional demands of each sector:

- **Commercial Buildings:** High-rise offices and shopping malls, where PV arrays on roofs and FSLSCs on facades optimize urban energy generation.
- **Public Infrastructure (Stadiums, Airports):** Large, continuous power requirements demand extensive PV and FSLSC use on roofs and facades for maximum output.
- **Educational Institutions:** Schools and universities benefit from mid-scale systems with a low-maintenance focus, using smaller FSLSCs and rooftop PV panels.
- **Healthcare Facilities:** Hospitals require high reliability, so designs for healthcare incorporate battery storage and enhanced monitoring.
- **Industrial Complexes:** Factories and warehouses benefit from large-scale FSLSC and PV installations, optimized with real-time energy monitoring.

Each product family offers different tiers (e.g., L1, L2, L3), tailored for varying capacity, budget, and design needs, ensuring that each market segment receives a solution optimized for its specific requirements.

Risk Management and Product Variability

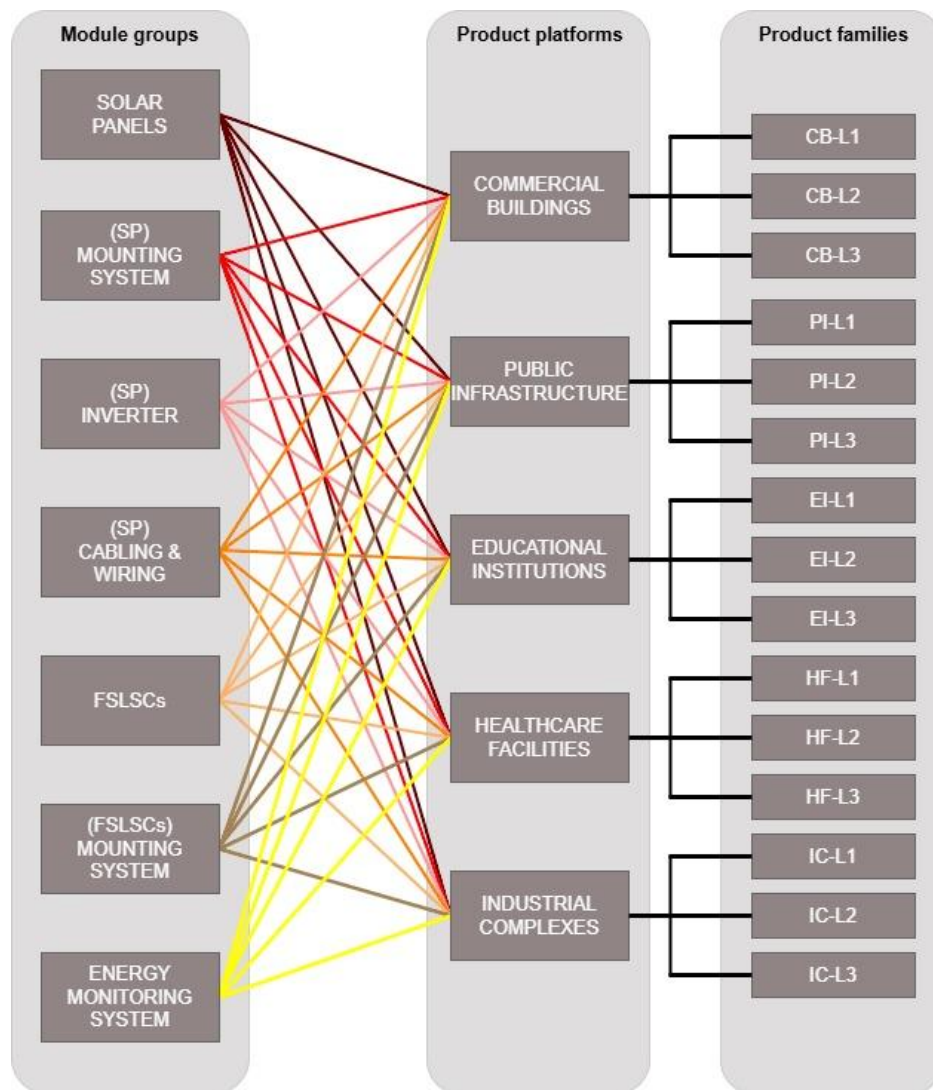
A major advantage of PDPD is risk mitigation through standardized, adaptable modules. This modularity allows for easy maintenance, as we can upgrade individual components without altering the entire system. PDPD also supports variability across budgets and architectural designs, with options that range from a budget FSLSC-PV system to premium variants with advanced monitoring and aesthetic customization. This flexibility broadens our client base and minimizes financial risk by allowing tailored solutions that meet diverse economic and operational needs.

Expanding Beyond Stadiums: Market Applications

While our primary focus is on Grolsch Veste Stadium, PDPD enables the FSLSC-PV system to be easily adapted to additional markets. This flexibility enhances the potential reach and long-term value of our system:

- **Commercial Buildings:** High-rise offices and malls, where PV arrays and FSLSCs on facades enhance urban energy generation.
- **Public Infrastructure:** Airports, train stations, and government buildings benefit from PV and FSLSC configurations for high energy demands.

- **Educational Institutions:** Universities and schools need mid-scale installations that balance cost savings with sustainability.
- **Healthcare Facilities:** Hospitals gain reliable, decentralized energy generation with backup systems.
- **Industrial Complexes:** Factories and warehouses benefit from substantial on-site power generation and real-time energy monitoring.



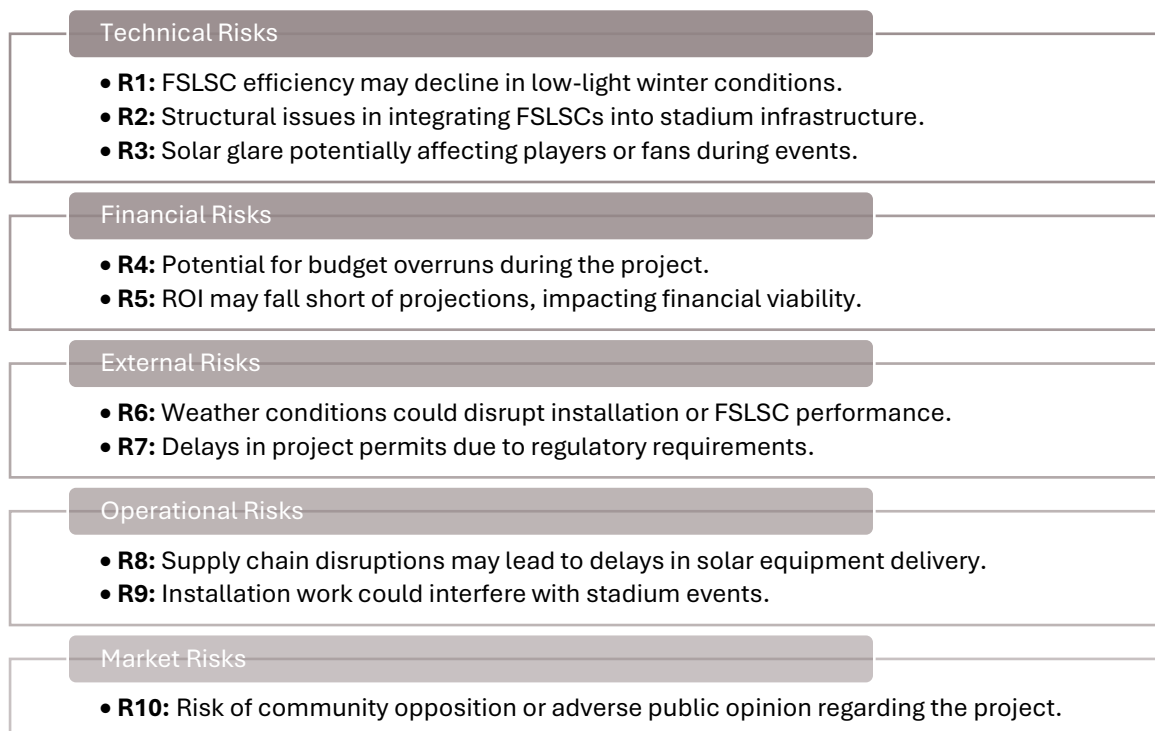
Product platform for the Grolsch Veste FSLSC-PV project is illustrated above. To complete a fully modular system for the FSLSC-PV design, we implemented a core set of standardized modules that enhance scalability and flexibility. This foundational design supports seamless customization, making the product adaptable for various market segments. By emphasizing modularity, we ensure that the system remains versatile and can meet diverse energy and structural needs across multiple applications, positioning it as a flexible solution for a broad range of infrastructure environments.

Risk Diagnosing Methodology

In our project, we leveraged insights derived from the Delft Innovation Model, specifically by analysing trends, competitor actions, and conducting a SWOT analysis. This foundation clarified our objectives and established the context for implementing solar technologies within the stadium:

- Optimize energy production by utilizing FSLSCs and PV panels on stadium surfaces.
- Enhance sustainability and public image with a green brand projection.
- Reduce long-term energy costs through renewable sources.
- Ensure durability and low maintenance of solar systems with a focus on longevity.

Our primary stakeholders include stadium management, local government, energy suppliers, sponsors, and fans, each influencing the project based on unique priorities such as regulatory compliance, energy efficiency, and public appeal. In considering the broader context, we align with environmental regulations and sustainability standards, ensuring green practices throughout the project. Additionally, growth in the renewable energy market supports our project's strategic relevance, while advances in solar technologies allow us to integrate the most efficient, cutting-edge solutions. Together, these factors provide a solid foundation for addressing risks and aligning the project with both stakeholder expectations and technological progress.



After establishing our project goals, we brainstormed and reviewed similar projects alongside competitor approaches to identify potential risks, as illustrated above. Organizing risks into distinct categories allowed us to design targeted solutions to address each one effectively.

We developed a risk questionnaire, which can be found in Appendix 1: RDM Questionnaire, to classify risks based on three key factors: Certainty (C), assessing the likelihood of occurrence; Ability to Influence (A), evaluating our capacity to manage the risk; and Importance (I), measuring its significance to project success. Although we did not administer the questionnaire to participants, we based our assumed results on insights from similar projects. This scoring system enabled us to prioritize risks and create targeted mitigation strategies.

With a cautious approach to risk, our project focuses on minimizing high and fatal risks to ensure stability while aiming for long-term success. Consequently, we prioritized developing mitigation strategies for only the most critical risks identified: **R1 (FSLSC efficiency)**, **R2 (Structural integration issues)**, **R3 (Solar glare impacts)**, and **R4 (Budget overruns)**. This focused approach allows us to allocate resources effectively and manage the project's most immediate and impactful risks.

#	Risk Statement	Risk Class
R1	FSLSC efficiency lower than expected due to limited sunlight during winter.	H
R2	Structural issues with integrating FSLSCs into the stadium.	H
R3	Supply chain issues for solar equipment impacting installation timelines.	L
R4	Weather conditions affecting installation and performance of FSLSCs.	H

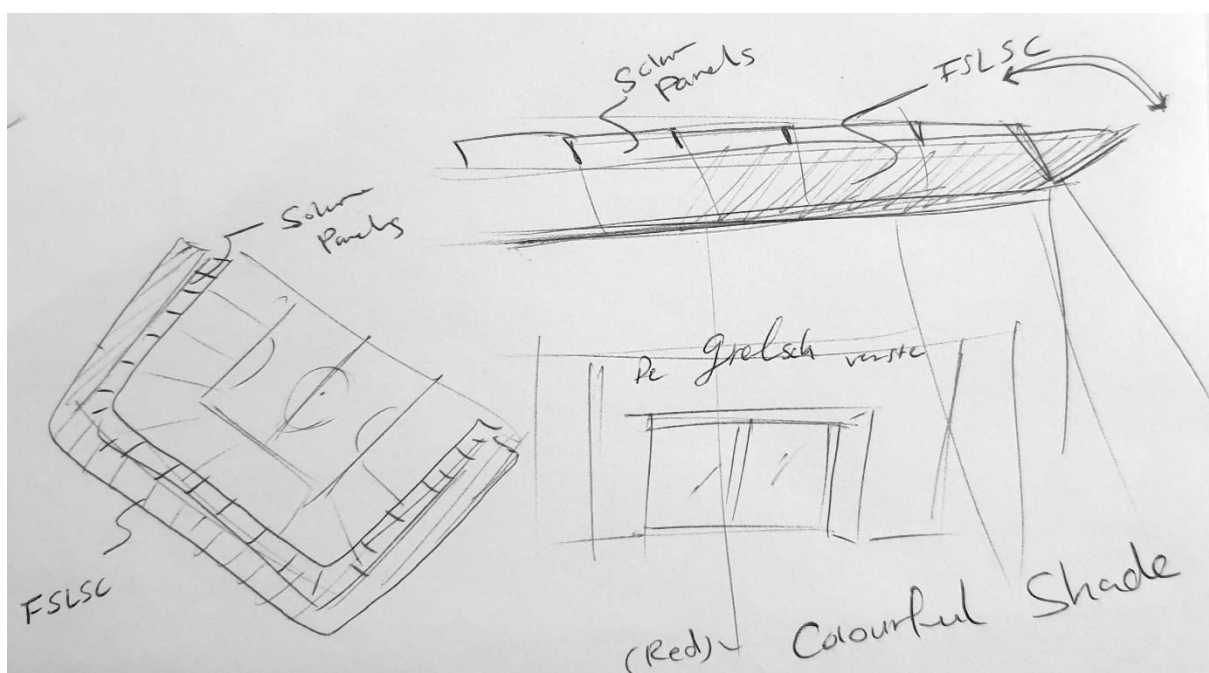
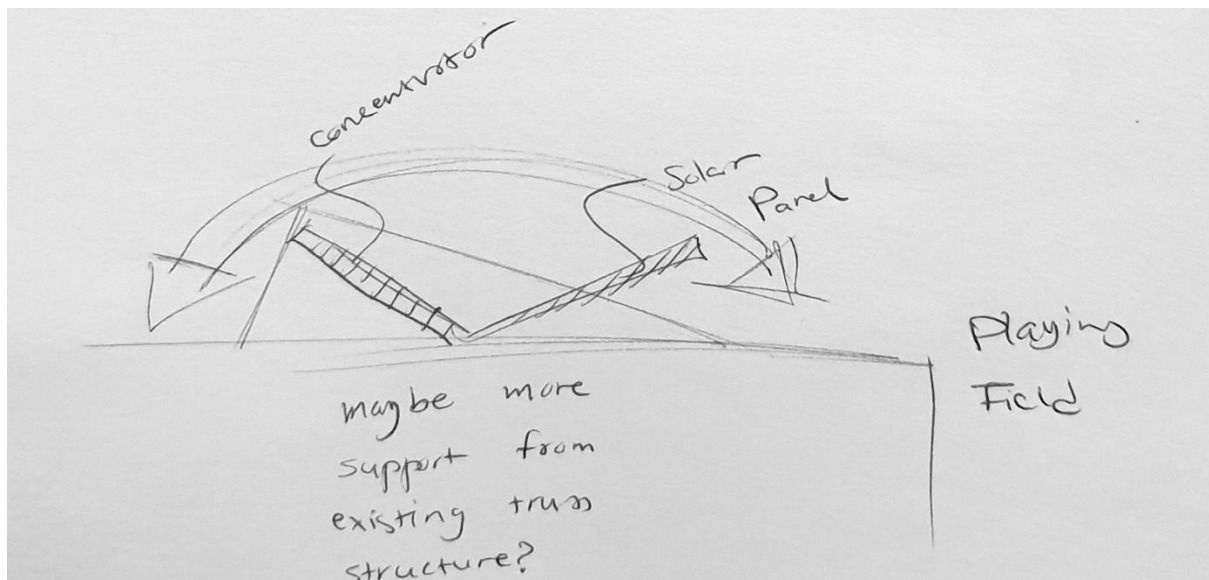
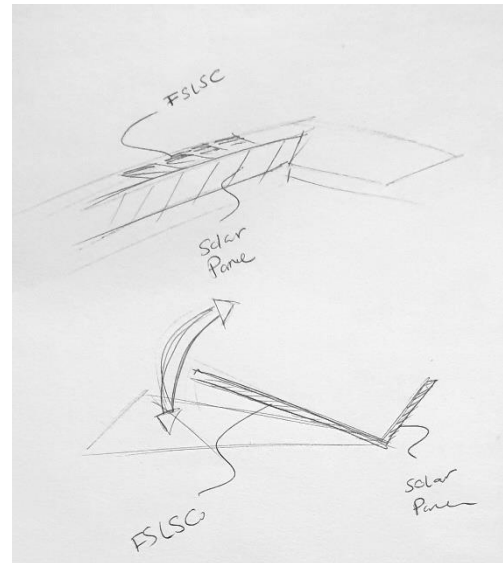
In next step, we prioritized the risks, and chose mitigation strategies, and the rationale behind each approach. Our strategies include attending to the uncertainty level for high variability risks, allowing for dynamic adjustments based on new information. We apply risk transfer and contracting to shift responsibility and reduce exposure, while risk hedging diversifies actions to limit potential losses. Risk evasion adjusts designs to avoid foreseeable issues, risk controlling reduces impact through planned measures, and risk acceptance allows manageable risks to be overlooked, focusing resources on significant threats (Moya et al., 2017).



It is important to note that we have not developed a formal Risk Management Plan at this stage due to time constraints and the scope of our project. The next logical step would typically involve creating and executing a detailed plan where each identified risk would be assigned an owner and specific actions outlined for effective mitigation.

Design Evolution

Reflecting on our concepts and ideas using the four tools, we concluded that the roof has the most potential. We then proceeded with calculations and reviews of the roof concepts. Different configurations regarding placement on the roof and the movability of the design were considered. This stage involved balancing performance metrics, with break-even points identified for optimization during the finalization phase.



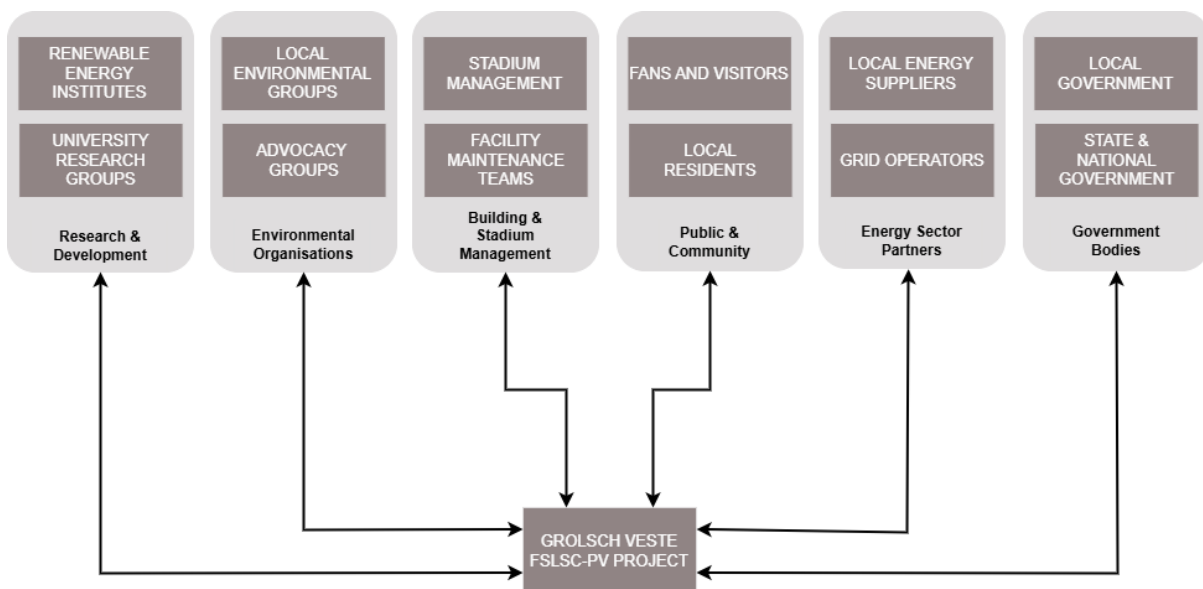
Finalization Phase

Constructive Technology Assessment

The constructive technology assessment (CTA) considers five key steps: 1) Engagement with Multiple Stakeholders, 2) Anticipating and Reflecting on Societal Impacts, 3) Creating “Bridging Events” for Mutual Learning, 4) Scenario Development and Sociotechnical Implications, and 5) Strategic Intelligence Integration. For our context, we focus on Stakeholders, Societal Impact, Scenario Development, and Strategic Intelligence Integration, as these three steps are the most relevant for our project.

Engaging with Stakeholders

We identified a variety of stakeholders and grouped them based on their interests. For efficiency, we include renewable energy institutes, stadium management, and energy sector partners who want to optimize energy use. Local and national government bodies play a key role in legislation, helping us navigate regulations. We will also seek financial support from universities and research groups for grants, as well as from local government for potential subsidies. Our aesthetic considerations involve fans, visitors, and local residents who care about how the installation looks. Lastly, safety is a priority for the stadium and facility maintenance teams who ensure the structure is secure. While not every stakeholder engagement will directly affect our design, mapping out this network helps us understand everyone's concerns and roles.



Addressing Societal Impacts

A significant factor in our design is the history of roof collapses at the stadium, which highlights the need for structural safety. We plan to place the FSLSC and solar panels directly under the supporting structure to reduce stress on the roof and better distribute weight. This approach not only addresses safety concerns but also helps avoid expensive repairs down the line.

Scenario Development and Strategic Intelligence Integration

We expect our system to generate about 400 kWh on regular days and up to 5000 kWh on full match days. Our design includes modular triangular FSLSC panels and solar panels, each measuring 11x10 meters. We've decided to position the panels on the southwest side of the stadium based on efficiency calculations, while also considering the southeast side as an option if it proves feasible. The northwest side will not generate a significant amount of energy and will be discarded. This strategic placement aims to maximize energy production while balancing technical requirements. Maintenance for solar panels is estimated to be around 1 to 3 times a year.

In conclusion, while our stakeholder analysis did not significantly affect our design, our consideration of societal impacts led us to position the FSLSC and solar panels strategically. With numerical values, we can now execute preliminary calculations for energy generation for the Grolsch Veste football stadium. Considering the results of other models regarding aesthetics, the preliminary design includes the FSLSC and solar panels only on the southwest side to provide symmetry.

Innovation Design & Styling

Innovative Design and Styling was the final tool we applied in our project, serving as a meaningful culmination of our innovation strategy. This step built on earlier insights by enhancing the visual and functional integration of technology within the stadium, solidifying its identity while balancing novelty and typicality. This approach ensured the project's energy-efficient technology not only functioned optimally but also communicated its purpose effectively through design. By adhering to Raymond Loewy's MAYA principle (Most Advanced, Yet Acceptable), we created a groundbreaking yet accessible final concept, supported by disruptive images to engage stakeholders and reinforce the stadium's commitment to environmental impact.

The implementation of this tool aimed to answer two key questions that guided the design process:

What do I want to communicate?

- We aimed to convey sustainability, innovation, and efficiency in the stadium's design. This communicates to stakeholders, sponsors, and fans that the stadium is actively pursuing green energy solutions, reinforcing its public image as an eco-friendly venue.

Which associations can I use to communicate this?

- To reinforce sustainability, associations were drawn from nature-inspired elements, such as integrating solar array patterns into architectural details. These subtle cues connect users with the concept of energy production, without overtly drawing attention away from the stadium's original design.

We took a structured approach by first identifying the essence of our sustainable energy objectives, then exploring product communication through eco-innovation metaphors, and finally balancing novelty and typicality in our design to ensure it feels innovative yet familiar.

Identifying the Essence

In our initial step, we focused on identifying the essence of the project's sustainable energy objectives. We distilled these core goals by considering how solar elements could be seamlessly integrated into the stadium's iconic structure without compromising its architectural integrity. This foundational abstraction laid the groundwork for exploring innovative yet harmonious design possibilities, ensuring that our approach would respect and enhance the existing aesthetic while promoting renewable energy solutions.

Exploring Product Communication

Next, we delved into exploring product communication by testing various design metaphors associated with “eco-innovation.” We aimed to visually convey the integration of renewable energy by incorporating subtle solar array forms into the stadium's structure. This strategic design choice was intended to help audiences form a clear visual association between the stadium and sustainable , designed with gaps to allow natural light onto the field.



Balancing Novelty and Typicality

Finally, we focused on balancing novelty and typicality in our design process. Drawing on the concepts from Hekkert et al. (2003), we aimed to create a design that felt fresh and innovative without appearing alien or out of place. This balance was essential to convey the innovative nature of our project while ensuring that the design remained grounded and familiar to the audience. In the image on the left page, we presented a vertical facade of the building, showcasing blue solar panels with red FSLSCs resembling floating fabric, which helps to maintain the essence of the stadium while embracing a modern aesthetic. This evolution effectively illustrates how our design maintains traditional elements while introducing innovative features, complemented by the image on the right page, which highlights the integration of solar elements into the stadium's iconic design.



Overall Design Outcomes

At this point of the report, we were able to set up and review a detailed design according to all performance indicators obtained from the models, KPI's and calculations. The details are provided in the next chapter and outputs are shown in the Key Performance Indicators and calculations overview.

	Models	Before	After
1	Delft	We chose the context of Grolsch Veste Stadium.	We gained insights about stakeholders and conducted a SWOT analysis.
2	TRIZ	We identified contradictions.	We developed specific solutions from TRIZ, leading to three concepts that addressed modularity, scalability, functionality, and colour.
3	PDPD	We developed three concepts.	We verified concepts regarding modularity and scalability and aligned them with the results from the previous model.
4	RDM	We identified potential risks.	We decided on the roof concept based on the identified risks for other concepts.
5	CTA	We assessed the roof concept positioning.	We verified stakeholders, added numerical assumptions, and conducted preliminary dimensioning.
6	Innovation Design & Styling	We assessed the roof concept positioning.	We finalized a complete detailed design configuration, primarily focusing on the south-west side with a dual angle setup.

Final Concept

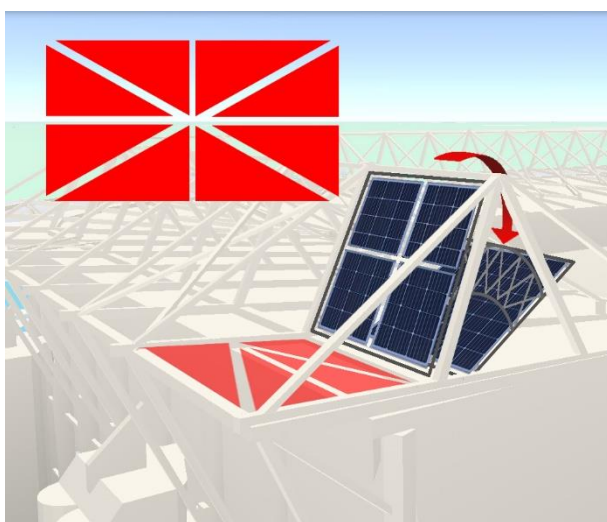
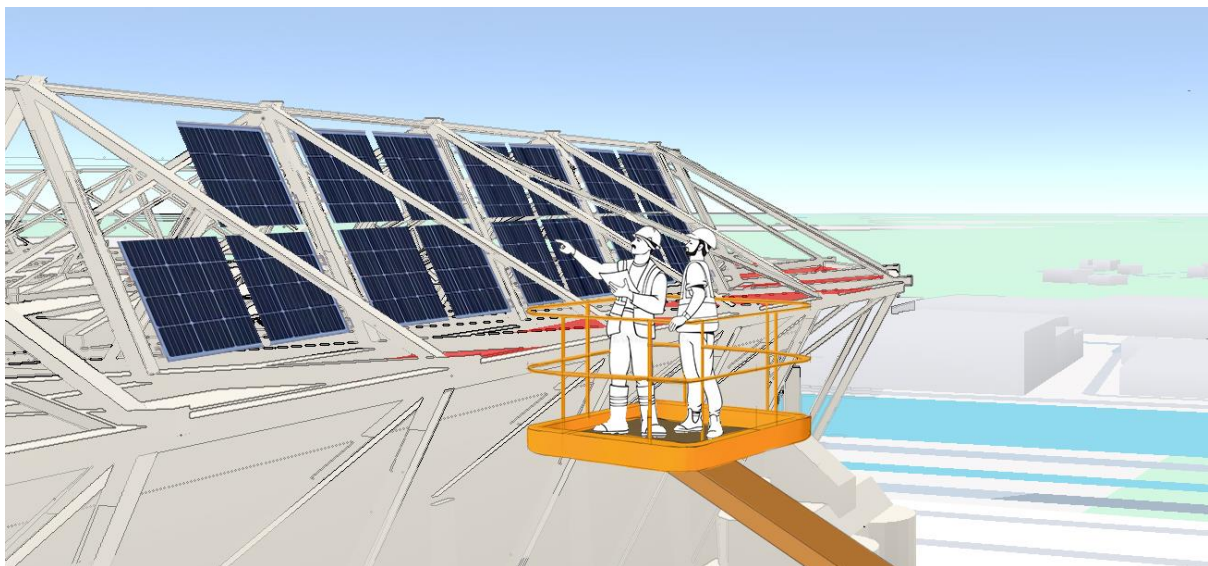
The final concept is developed with the help of the results of the models. In the first phases a general analysis was executed including stakeholders. Functionality, effectiveness, durability, modularity and aesthetics were key points for generating the contexts as well as the first concepts for the stadium. This awareness provided by the models cancelled out a significant amount of ideas regarding contexts. The second phase models provided a more in-depth insight regarding the concepts for the stadium. This helped especially in the second phase for determining which concept could work best. The last phase provided a guidance which led to the final concept with specific features and calculations for the chosen set-up.



As illustrated in the figure, the configuration primarily occupies the south-west side of the stadium. The red panels represent the FSLSCs, while the blue panels are the solar panels integrated into the stadium roof. We decided on a symmetrical overall look to enhance visual harmony. As can be seen in the figure, the colouring of the FSLSC ensures that the panels blend nicely with the stadium's appearance, contributing to a more majestic overall look.

The final design is modular, featuring uniform-sized solar panels mounted on the existing roof truss frame through an intermediary framework. Although we did not detail this framework, we envision it constructed from lightweight, durable steel that meets the requirements of our various models. The solar panels and FSLSCs connect to this framework using a snap-fit mechanism, facilitating easy maintenance. For ease of maintenance and segmentation, the panels are arranged into four triangular units per truss instead of one large rectangle.

Positioning our design on the roof's outer side allows convenient access for maintenance checks, which will be conducted one to three times a year. During these sessions, the maintenance expert will adjust the angle of the solar panels based on seasonal sunlight patterns, optimizing efficiency throughout the year.



The FSLSCs consist of two types, designed as asymmetric right triangles that fit together like a puzzle within the square framework of the existing roof truss. As depicted in the images, when two pieces (eight panels together) are combined, they resemble the logo of Enschede, casting interesting shadows on the floor and facade. We selected red for the panels for two reasons: it achieves maximum efficiency among FSLSCs and aligns with the dominant colour associated with Grolsch Veste.



Calculations

The designed set-up has a summer angle and winter angle for the solar panels. Both FSLSC and solar panels are mostly directed towards the South-West. In this set-up the FSLSC lay flat and the solar panels during summer are angled at 16 degrees and during winter angled at 65 degrees.

The change of angle can be done manually which could be included in the maintenance procedures. Maintenance for Solar panels is estimated to be around 1 to 3 times per year which fits along with changing the angle for the solar panels. End September/begin October and end March/begin April are the calculated times for this change to be optimal regarding energy generation.

From the setup a power output of roughly 3.400.000 kWh is generated, where roughly 1/5 of the energy is generated by the FSLSC. Contextualize this result it means the setup could provide 362 days of non-match days (est. 400 kW) and 29 days of full match days (est. 5000 kW). Comparing the set-up for energy generation with and without FSLSC the efficiency without FSLSC is 3,69 kWh/eu and with FSLSC is 3,72 kWh/EU. This means the FSLSC according to calculations is increasing the efficiency for the set-up defined by energy generation in kWh per invested euro.

The calculation model has been altered in a way that would provide results in a more realistic way with our configuration. In more detailed words, the percentage of the emission cone of the FSLSC that is directed towards the solar panels is considered and added as a reduced factor on the generated energy. Still the efficiency factor of the FSLSC is considered for the total calculations.

Regarding the estimations for the weight on the roof FSLSC, solar panels and frameworks will be considered. The estimated weight of the FSLSC would result in 36.000 kg, solar panels 60.000kg and the frameworks 96.000 kg. This would result in a total weight of 192.000 kg over a surface area of roughly 6.000 m². This is a weight distribution of 32 kg/m². According to standards ASCE 7-16 and Eurocode 1 EN 1991-1-1 stadium roofs are intended to carry loads with ranges like 50-100 kg/m². It is important to keep in mind that Grolsch Veste had issues before with the construction of the roofing and we are not aware of the values specifically for this stadium.

Key Performance Indicators

Annual Yield

As stated in the calculations we accounted for the dual angle set-up with the winter and summer configuration. This generated roughly 2.800.000 kWh with only the solar panels and estimated costs would be €750.000,-.

Annual Enhancement

The introduction of the FSLSC would provide for an additional generated power of roughly 600.000 kWh and an additional cost estimated around €150.000,-. This would in total generate 3.400.000 kWh as mentioned earlier and cost around €900.000,-.

Payback time

With the assumption that one kWh would cost the “Grolsch Veste” 35 cents, it can be calculated that the generated energy per year would be worth ($€0,35 \times 3.400.000 \text{ kWh} =$) €1.190.000,-. This results in a payback time of ($\frac{€907.500}{€1.190.000} \times 100\% =$) 0,76% of a year which is roughly 9 months.

Self-Consumption Index

This index is defined as the yield in July divided by the yield in December. For the system with only Solar panels this would result in ($\frac{123,66 \text{ kWh}}{24,24 \text{ kWh}} =$) 5,10 and with the FSLSC the index would be ($\frac{123,66+141,94 \text{ kWh}}{24,24+13,27 \text{ kWh}} =$) 7,08.

Limitation and Discussion

In our project, we successfully integrated innovative energy solutions into the Grolsch Veste stadium design; however, we must acknowledge several limitations. While we identified key stakeholders, we did not actively engage them due to time constraints and limited resources. This absence of direct feedback led us to make assumptions based on results or research from similar projects, which may not fully reflect the unique context of the Grolsch Veste stadium. Consequently, the overall acceptance of our design could be impacted.

Additionally, our calculations relied on historical data and existing models, meaning the accuracy of our energy generation estimates could be affected by changing environmental conditions and variations in stadium use. We were also constrained by the need to respect the architectural integrity of the existing structure, which limited our exploration of more radical alternatives. The proposed maintenance schedule is based on theoretical considerations, and practical implementation may face unforeseen challenges, such as access difficulties that could impact long-term efficiency. Furthermore, our financial estimates are based on current market conditions, and fluctuations in energy prices may alter the project's viability over time.

Lastly, we executed this report with three students instead of the recommended four, resulting in the implementation of only six innovation tools rather than eight. Insights from the omitted models could have provided additional perspectives. We specifically chose the tools in a particular order, and altering this sequence might lead to different design outcomes, highlighting the importance of methodological choices in our innovation process.

Conclusion

Our overall design process was supported by the selection of six models: the Delft Innovation Model, TRIZ, Platform Driven Product Development (PDPD), Risk Diagnosing Methodology, Constructive Technology Assessment, and Innovation Design & Styling. These models provided a structured framework across three phases, allowing us to gather insights at each stage.

In the first phase, we found the Delft Innovation Model particularly useful for understanding the context of the Grolsch Veste stadium. While TRIZ could have played a stronger role in later stages, it still helped us identify potential design challenges. The second phase leveraged PDPD and Risk Diagnosing Methodology, refining our approach by focusing on modularity, risk assessment, and stakeholder engagement.

Feedback from our initial presentation emphasized the value of PDPD for modular and standardized design. We listened to this recommendation, and PDPD proved instrumental in structuring our design process, enabling us to integrate visual ideas and align with stakeholder expectations. Incorporating visual concepts that we had previously overlooked enriched our presentation and clarified our innovative design intentions.

Feedback from the second session encouraged us to showcase how our design evolved through the various methods. We aimed to detail our calculations and highlight the design's adaptability, ensuring clarity in our final presentation. Both feedback sessions were insightful, providing constructive guidance that allowed us to refine our approach without significant negative critiques.

In our final phase, we utilized Constructive Technology Assessment and Innovation Design & Styling to ensure that our design met both functional and aesthetic requirements. Our calculations and Key Performance Indicators indicated that our design could offer attractive long-term financial benefits while adhering to sustainable strategies. The models also enhanced our awareness of stakeholder preferences, resulting in a configuration that balances visual appeal with functionality.

Reflecting on the innovation methods we employed, each provided unique insights valuable for product design. The positive reactions during our feedback sessions emphasized the innovativeness of our product concept, highlighting its efficiency and visual integration with the stadium. For a full-scale version, we recommend further exploration of stakeholder engagement strategies and potential partnerships to enhance the implementation process.

Future Research

In our future research, we could investigate the structural properties of the Grolsch Veste stadium to verify the viability and safety of our design. Additionally, we can further utilize the TRIZ model to address low-importance contradictions that emerged during our analysis. Specifically, we should explore the following contradictions: Performance Monitoring versus System Complexity, Seasonal Performance versus Aesthetic Appeal, System Scalability versus Specialization for Grolsch Veste, Environmental Impact versus Material Selection, and Reliability versus Innovation. By addressing these contradictions, we can develop more refined solutions that enhance functionality while preserving the stadium's iconic aesthetics.

During our second feedback session, it was recommended that we consider a Multilevel Design Model to better engage with our stakeholders. This model could facilitate a more comprehensive understanding of the various interests and concerns of different stakeholder groups, such as stadium management, local government, and community residents. However, due to time constraints, we opted not to incorporate this model into our project. Nonetheless, we believe that integrating a Multilevel Design Model would be valuable for future work, as it could significantly enhance stakeholder engagement and result in a design that better aligns with community needs.

We also recognize that we did not develop a formal Risk Management Plan due to time constraints. A logical next step would involve creating a detailed plan where each identified risk is assigned an owner, along with specific actions for effective mitigation. Moreover, exploring stakeholder engagement strategies and potential partnerships could enhance the implementation process, ensuring our design meets both functional and aesthetic requirements while aligning with community interests.

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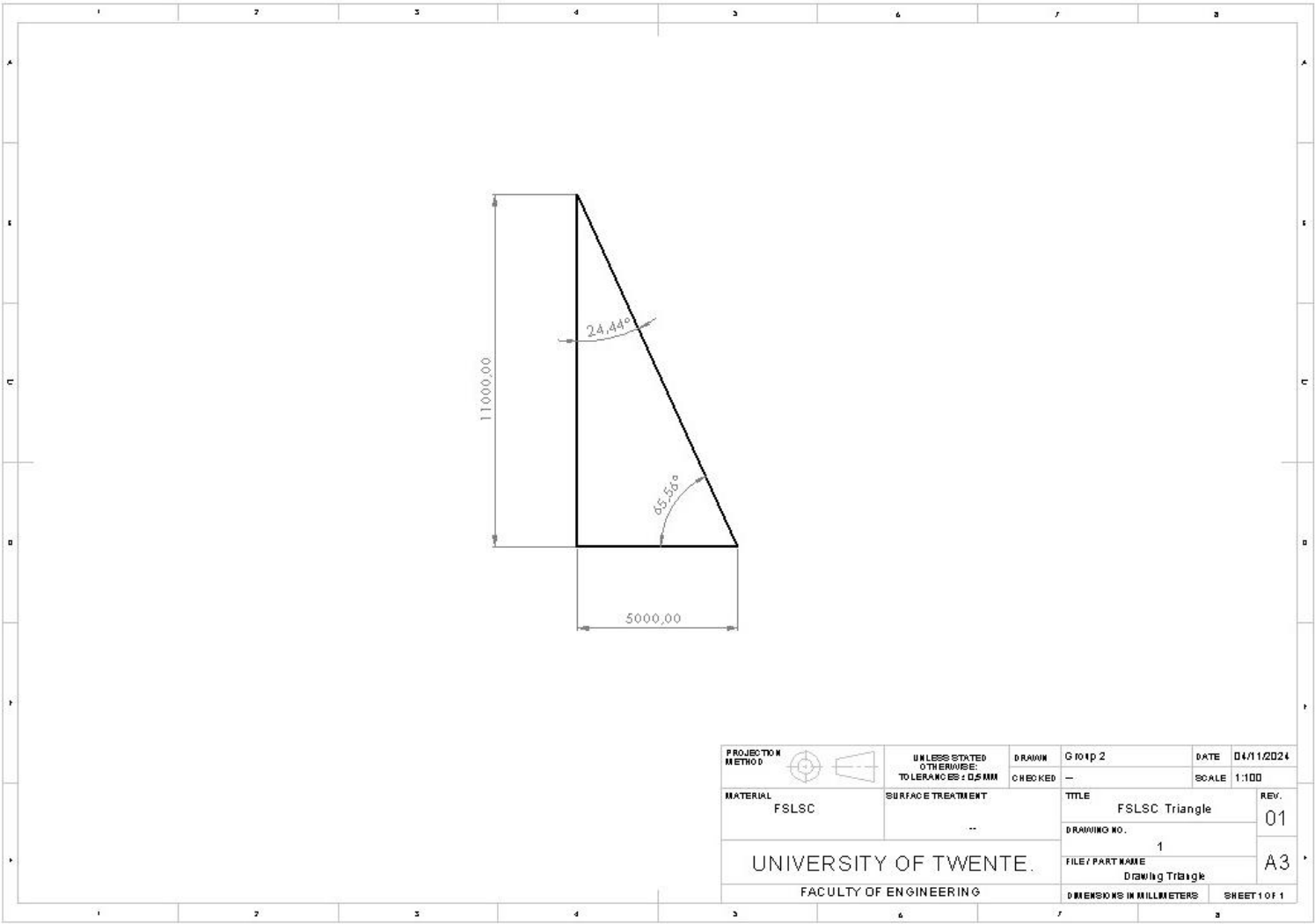
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Appendices

Appendix 1: RDM Questionnaire

#	Risk Statements	What is the level of certainty that the statement will be true?					Ability of team to influence course of actions within time & resource limits					Relative importance of statement for obtaining project success					Score for each dimension of risk				Risk Class
		(C)					(A)					(I)									
		Very Low	Low	Medium	High	Very High	Very Low	Low	Medium	High	Very High	Very Low	Low	Medium	High	Very High	C	A	I		
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5					
1	FSLSC efficiency lower than expected due to limited sunlight during winter.																5	4	4	H	
2	Structural issues with integrating FSLSCs into the stadium.																3	5	4	H	
3	Supply chain issues for solar equipment impacting installation timelines.																2	2	4	L	
4	Weather conditions affecting installation and performance of FSLSCs.																4	3	4	H	
5	Budget overruns impacting overall project viability.																3	4	4	M	
6	Return on Investment (ROI) may not meet expectations.																3	3	4	M	
7	Delays in project completion due to supply chain issues for solar equipment.																3	2	4	M	
8	Disruption to stadium events during installation.																2	4	3	M	
9	Potential for solar glare affecting players or fans during matches.																3	4	3	M	
10	Permitting delays from local authorities.																3	3	4	M	

Appendix 2: Technical Drawing



Solar Sync Stadium
Solar Sync Stadium
Solar Sync Stadium

Appendix 3: Calculations

Winter	Parameter	Unit	Value		Summer	Parameter	Unit	Value		Total								
	Y_c	kWh/m^2	209,72			Y_c	kWh/m^2	741,24			Costs/area	€/m^2	PV	FSLSC	Total			
	Y_sp	kWh/m^2	261,56			Y_sp	kWh/m^2	660,46								250	50	
	Angle Solar Panel	°	16			Angle Solar Panel	°	65								3025	3025	
	Efficiency factor FSLSC	-	0,6			Efficiency factor FSLSC	-	0,6								756250	151250	907500
	w_c	m	11			w_c	m	11										
	l_c	m	275			l_c	m	275										
	w_sp	m	11			w_sp	m	11										
	l_sp	m	275			l_sp	m	275										
	w_d	m	11			w_d	m	11										
	l_d	m	275			l_d	m	275										
	d	m	0			d	m	0										
	Y+_c	kWh	38064,18			Y+_c	kWh	546548,7			Y+_c	kWh	584612,9					
	Y+_sp	kWh	791219			Y+_sp	kWh	1997892			Y+_sp	kWh	2789111					
	Y+_tot	kWh	829283,2			Y+_tot	kWh	2544440			Y+_tot	kWh	3373723					
	Angle to begin	°	0			Angle to begin	°	0			Efficiency							
Angle to end	°	8		Angle to end	°	32,5		w/o FSLSC	kWh/eu	3,68808								
Angle cone	°	80		Angle cone	°	80		with FSLSC	kWh/eu	3,717602								
Angle factor	-	0,1		Angle factor	-	0,40625												
kWh per month		SP	C	kWh per month		SP	C	KPI										
October	kWh	57,92	49,05	April	kWh	106,86	116,47	July/December	5,101485	7,080778								
November	kWh	35,29	22,48	May	kWh	120,62	137,81											
December	kWh	24,24	13,27	June	kWh	122,75	142,04											
January	kWh	27,36	17,17	July	kWh	123,66	141,94											
February	kWh	42,99	33,87	August	kWh	105,94	118,24											
March	kWh	73,76	73,88	September	kWh	80,63	84,74											
Total Winter SP energy production	kWh	261,56	209,72	Total Summer SP energy production	kWh	660,46	741,24											