EUDP

64021-1079 UNITSUN
PV INTEGRATED IN PREFABRICATED FACADE SYSTEMS.

Final report
June 2024

Contents

1. Project details

Project title	UnitSun - PV integrated in prefabricated facade systems.
File no.	64021-1079
Name of the funding scheme	EUDP Development
Project managing company / institution	HSHANSEN A/S
CVR number (central business register)	73492114
Project partners	MG Solar, DTU Electro
Submission date	30 June 2024

2. Summary

2.1 Project summary UK

- **The purpose of the project**

The UnitSun project addressed the need for sustainable building solutions by integrating photovoltaic (PV) technology into prefabricated façade systems. The project developed and demonstrated innovative BIPV modules that combine aesthetic appeal with energy efficiency, setting new standards for fire safety and system integration.

- **Results, conclusions and perspective**

The UnitSun project successfully developed fire-resistant BIPV modules that meet Class B standards. The project created efficient electrical systems designed for minimal on-site assembly and designed and tested a variety of aesthetic options to meet demanding architectural requirements.

Additionally, a market-ready appearance catalogue and energy yield simulation tools were established. Extensive fire safety and performance testing demonstrated significant advancements in BIPV technology. Looking forward, HSHansen will refine the BIPV modules to achieve higher fire resistance ratings and streamline the integration process.

The project results will enhance sales materials and engage market stakeholders, promoting the adoption of BIPV systems. The UnitSun technology is poised to influence the future of BIPV systems, supporting sustainable building practices and contributing to energy efficiency. Aligning with the EU's RePower initiative, the project anticipates mandatory integration of photovoltaics in buildings, positioning UnitSun as a key solution for active façades.

2.2 Projektresumé Danish

- **Formålet med projektet**

UnitSun-projektet adresserede behovet for bæredygtige byggeløsninger ved at integrere solcelle (PV) teknologi i præfabrikerede facadesystemer. Projektet udviklede og demonstrerede innovative BIPV-moduler, der kombinerer æstetisk appel med energieffektivitet og sætter nye standarder for brandsikkerhed og systemintegration.

- **Resultater, konklusioner og perspektiv**

UnitSun-projektet udviklede med succes brandsikre BIPV-moduler, der opfylder klasse B-standarder. Projektet skabte effektive elektriske systemer designet til minimal on-site samling og designede og testede en række æstetiske muligheder for at imødekomme krævende arkitektoniske krav.

Derudover blev et markedsfærdigt udseendekatalog og værktøjer til energiydelsessimulering etableret. Omfattende brand- og ydelsestests demonstrerede betydelige fremskridt inden for BIPV-teknologi. Fremadrettet vil HSHansen forfine BIPV-modulerne for at opnå højere brandmodstand og optimere integrationsprocessen. Projektresultaterne vil forbedre salgsmaterialer og engagere markedsinteressenter, hvilket fremmer adoptionen af BIPV-systemer.

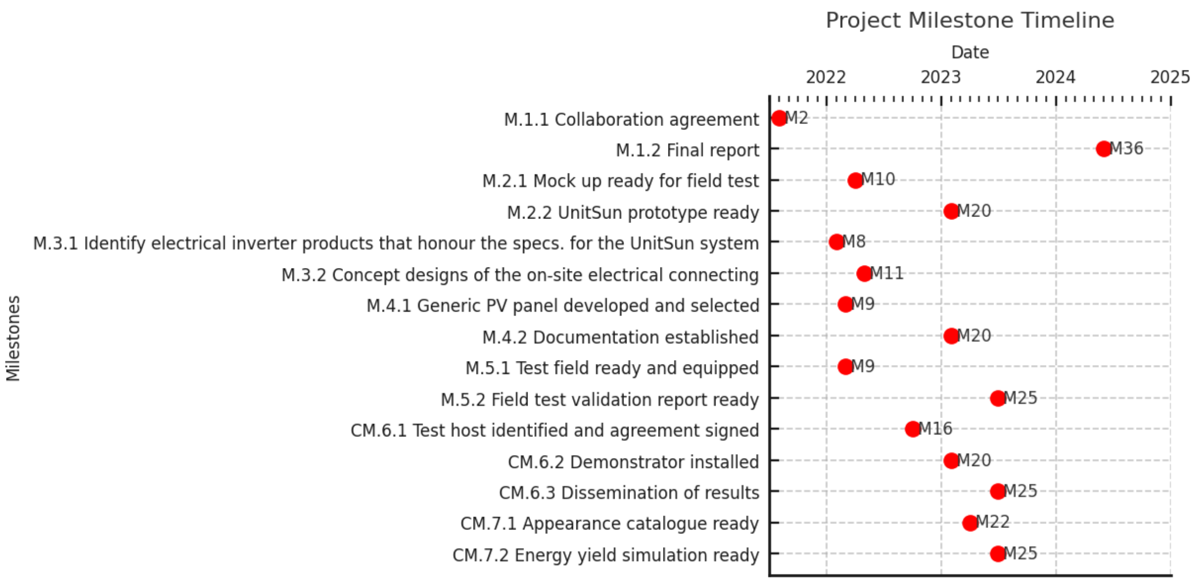
UnitSun-teknologien er klar til at påvirke fremtiden for BIPV-systemer, understøtte bæredygtige byggemetoder og bidrage til energieffektivitet. I tråd med EU's RePower-initiativ forudser projektet obligatorisk integration af solceller i bygninger, hvilket positionerer UnitSun som en nøgleløsning for aktive facader.

3. Project objectives

The purpose of the Unit-Sun project was to develop a Building integrated Photovoltaics (BIPV) versions of the HSHansen UnitAL prefabricated façade system, specificly to ensure:

- Solar cells was implemented in the façade system in a variety of appearances living up to even the most demanding architectural requirements for appearance and ensuring no visual discomfort from glare etc.
- The PV panel coloration method was selected to achieve the best compromise between efficiency, prices and colour appearance.
- The façade system was made to support cooling of the solar panels to ensure optimum electrical performance.
- The electrical system was developed so wires can be connected from module to module on the construction side with minimum effort. Inverters was integrated, and the electrical system made for optimum performance of the energy harvesting from the solar cells.
- The whole module system should be easily assembled in the factory in Lem, and the assembly system with the other elements perfectionated so minimal post-assembling need to be done on the construction side.
- The partners have ensured that the sub-elements as well as the assembled façade lives up to both building standards as well as standards for photovoltaic systems for easy approval of the system after the project, where it is introduced on the market 6 month after the project is finalized.
- We will developed several mockups, prototypes and it was originally the plan to end with a 1:1 installation at real test-host. The project was written into 5 tenders and 1 early on also one project already in the building phase was addressed with UnitSun. The challenge with addressing the façade is to have a good enough fire resistance. The fire resistance classes range from Class C (fundamental fire resistance), to Class B to Class A (highest fire resistance). Even though it was possible to live up to Class B it was still a challenge as class A is so much preferred.
- The development was done with focus on early introduction on the market ensuring sales materiel is built during the project (ownfinanced by HSHansen) and the building sites mockup and prototype was used for prepping the market and getting feedback from stakeholders.

Milestones are displayed in the Gantt chart below:



4. Project implementation

The project evolved efficiently and smooth and was divided into 6 work packages:

- **WP 1: Project Management**
- **WP 2: Mechanical development of façade system**.
- **WP 3: Electrical development, safety and**
- **WP 4: Optical development and characterization**
- **WP 5: Outdoor test bed**
- **WP 6: Demonstration**

The project management work package was designed to ensure efficient execution of the project with starting out with a kick-off meeting planning the whole project in details with the partners and afterwards running the project by dividing the WP in small efficient teams meeting every second week as a minimum for coordination and follow up on workplan and milestones.

The project had several technical and market risks which were all addressed as early as possible to ensure they had minimum impact on the project's progress, and it potentially could change direction. The project group had the needed competences to ensure the technical challenges were addressed though the primarily challenges was the market reactions to the solutions developed. The construction market have very limited experience with façade integrated photovoltaics and especially fire-safety was a challenge.

The fire resistance classes range from Class C (fundamental fire resistance), to Class B to Class A (highest fire resistance). A minimum fire resistance rating Class C is necessary for any building-mounted module (BAPV). Certification to a higher level may be considered in order to satisfy specific conditions and requirements. Depending on the building class, design criteria and other relevant aspects, PV modules integrated in buildings (BIPV) may require specific, more advanced characteristics as regards fire hazard than those tested by means of IEC 61730-2. As a rule, a minimum fire resistance rating Class A or Class B is needed. The project therefore took on the challenge to find a way of replacing the polymers inside the PV module with silicone and it can in that way achieve the Class B and do in principle live up to class A on fire spread as the silicone is preventing the fire from spreading. The calorimetric value of the silicone are though beyond a threshold preventing the class A certification.

The project were therefore not able to make a 1:1 demonstrator even though it was written into 5 tender processes and 1 already secured project where a part of the building was investigated for having the UnitSun solution integrated. There are therefore some market challenges where more knowledge and potential standards for BIPV could ensure dispensation for using the UnitSun solution. A building process is all about making compromises between components and the knowledge and standards on BIPV is just still in an early stage making this more difficult than for other materials. The building regulations in Denmark are also not favoring BIPV – on the contrary it is more like punishing it. This is also an unfortunate barrier that needs to be broken down, and work is therefore also being done by DTU in IEA Task 15 to address unreasonable barriers, just as the Danish solar cell association is used to change these unfairnesses. BIPV does not need to be given a special status, but it is not fair that the technology is punished.

The project partners are very satisfied with the technical results of the project fulfilling the milestones in time and the UnitSun will over time for sure be a solution meeting the demands of them market where energy production of the façade is becoming more and more attractive. It has though been a surprise to the project group that the BIPV market is still so immature. Luckily the RePower Europe initiative from the EU commission will at the end of the decade make it mandatory to integrate photovoltaics in buildings and the UnitSun solution will be an attractive solution for this.

5. Project results

All of the original project objectives were achieved as well as the milestones below is a detailed description of the results and milestones for each work package (apart from the 1:1 full-scale installation). The results are described below linked to their realization in the associated work packages.

5.1 WP 2: Mechanical development of façade system.

With the basis of the unit all systems several design options for embedding the PV-panels was investigated, including cable wrap conduits etc. A mock designs fitting to the testbed and compatible with HS hansen Unit-Al system was designed both one enabling a PV-based ventilated rainscreen and on where the rainscreen is non ventilated.

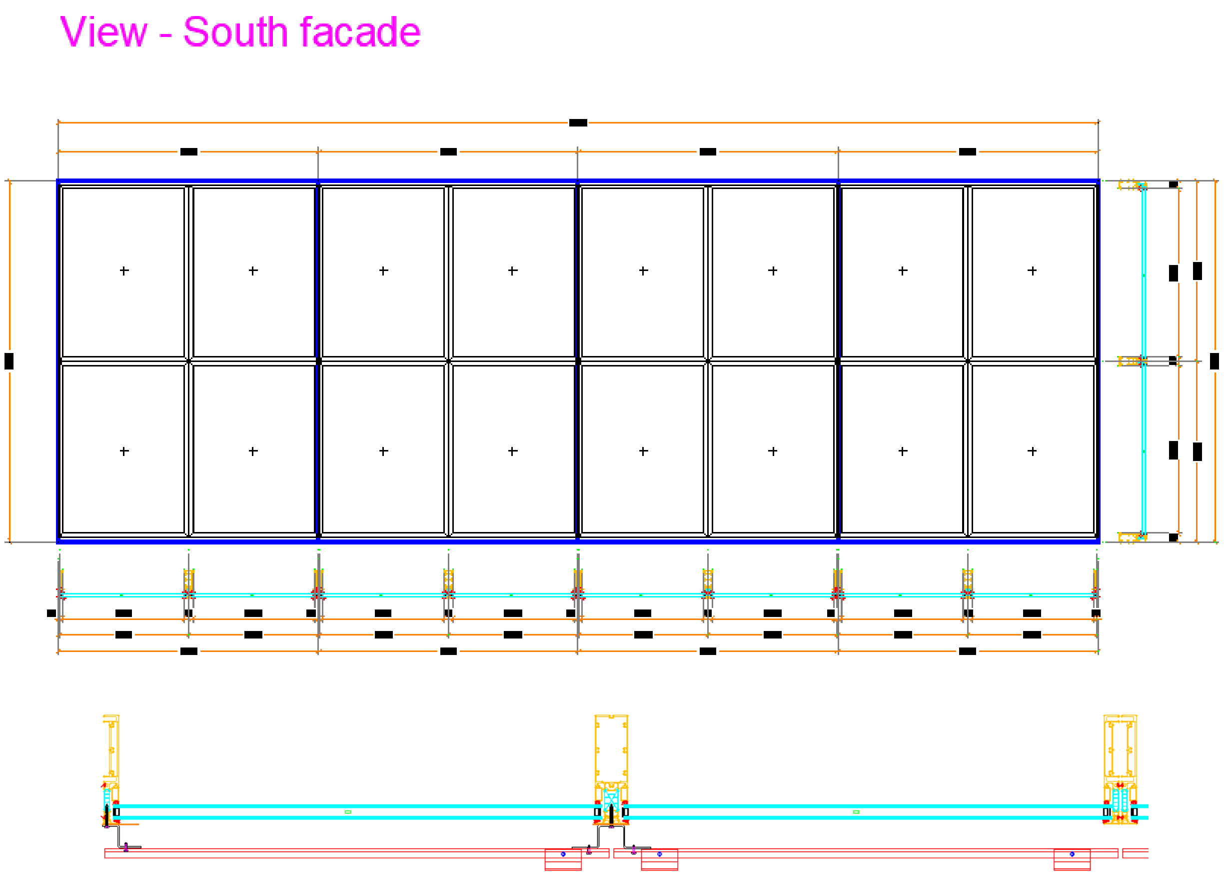


Figure 1: Over all design of the mock up.

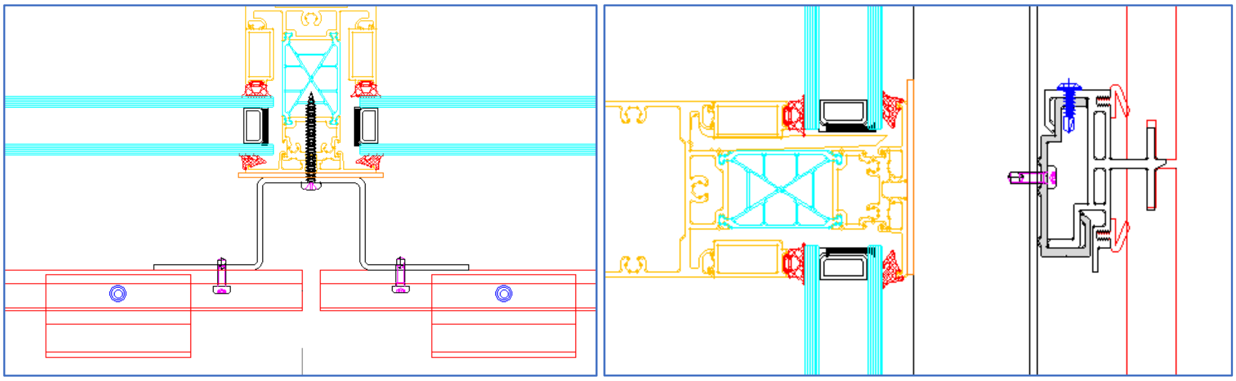


Figure 2: Mounting details for the ventilated rainscreen (left), and the nonventilated (right)

Prototypes of the mockup Unitsun systems were fabricated at HS hansen factory in Lem, in 3 different versions, so it fitted the test bed. The prefabrication concept was successfully demonstrated, also including the BIPV structures.

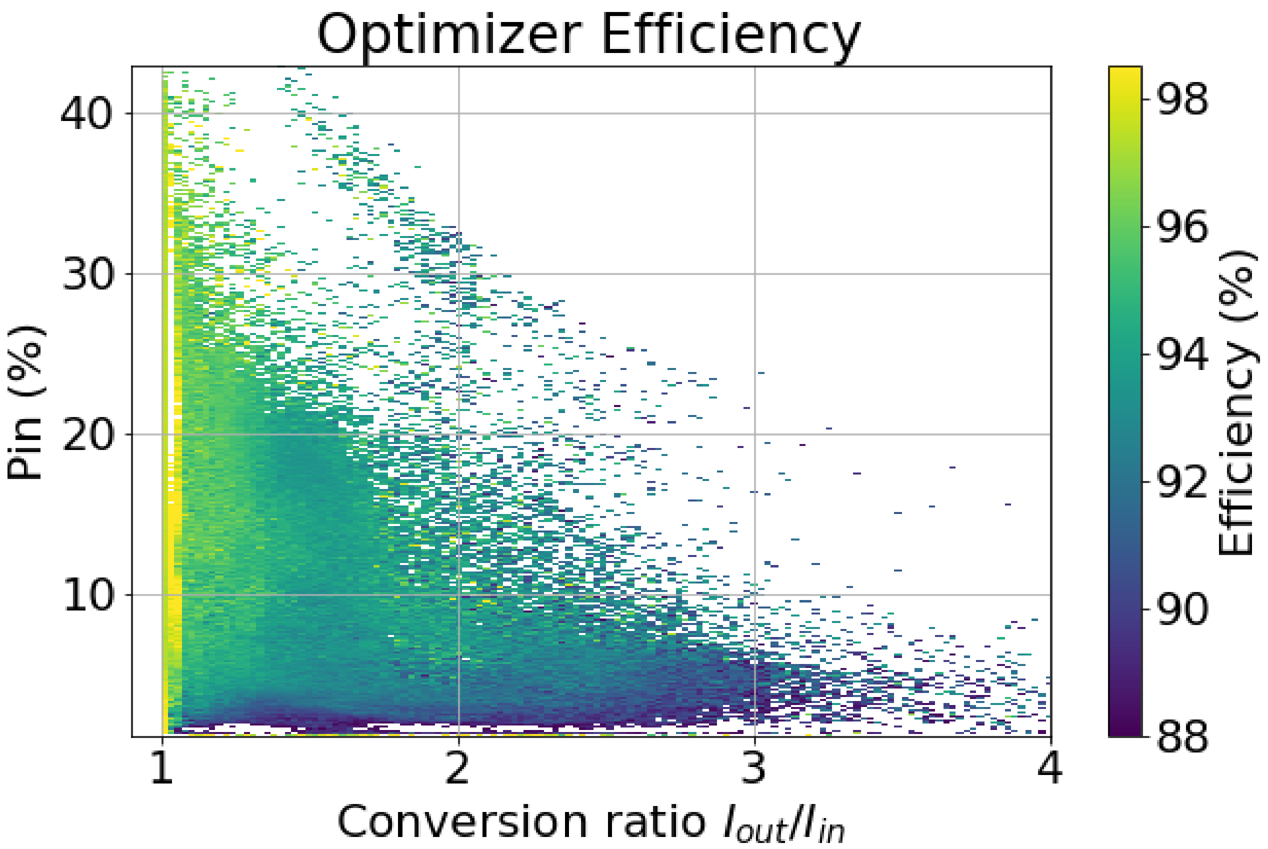
Figure 3: The Pre-fabricated elements arriving to DTU

5.2 WP 3: Electrical development, safety and firesafety

al inverter products that honoured the Unitsun system was identified to be a power optimizer system, where there is electrical optimization for each panel, and this output is feed into an inverter. Alternatives to this are µ-inverters where there is one inverter pr panel and string-inverters where one inverter optimizes several panels.

The single panel optimization combined with the fewer inverters offers the best solution in terms of price, shade tolerance as well as grid requirements and compliance to grid codes, and also this systems offer nearly a plug play solution, and a the same time in can be in compliance with grid requirements also for larger systems

The performance of an optimizer system was analyzed in the field, and some deviation from the datasheet efficiency was observed as well as a strong efficiency dependency on the mismatch level was observed, however despite the lower average efficiency the power optimizer system is still efficient, suited for different performing panels (e.g. due to different colors, and/or orientations) and further the distributed power electronics offers distributed safety features reducing electrical hazards.

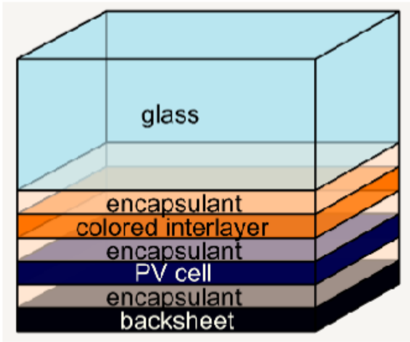


In addition, fire testing was performed, where different PV module configurations were tested in a Mini Single Burning Item at DBI, which is a small scale test indication a materials combustion ability.

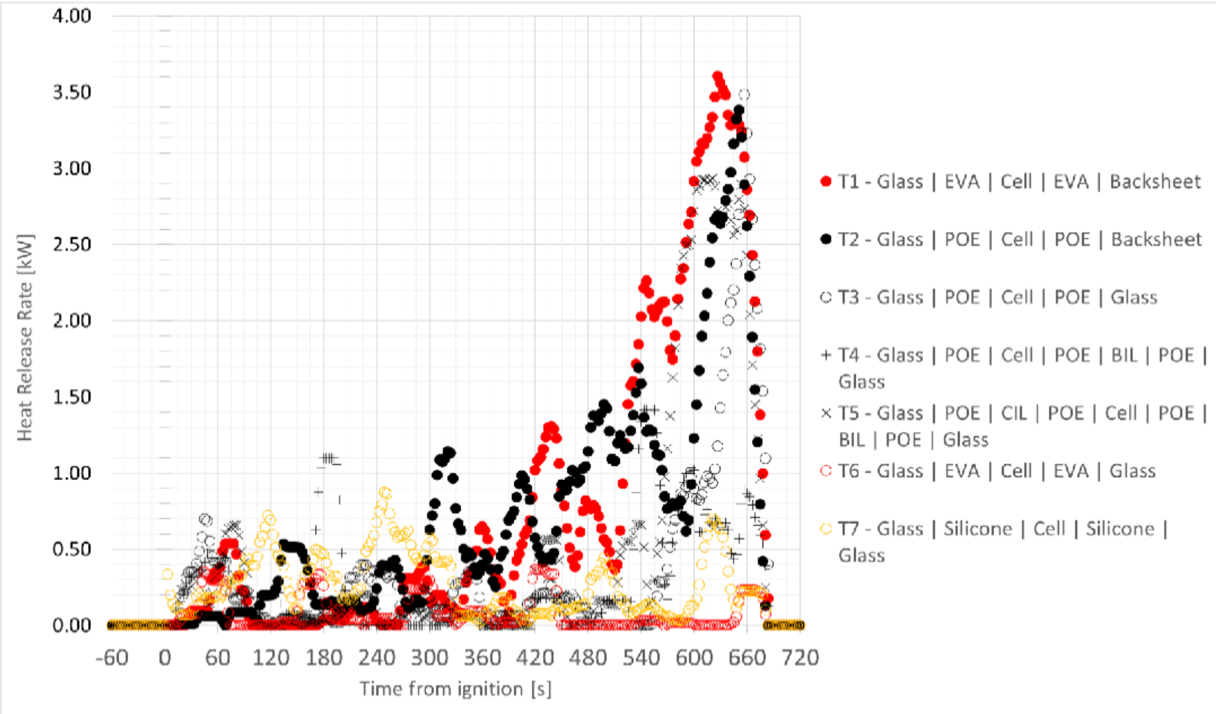
Figure 4: Mini Single burning item setup

Several module materials and configurations were tested, as shown in below figure:

Sample number	Module composition
1	Glass | EVA | Cell | EVA | Backsheet
2	Glass | POE | Cell | POE | Backsheet
3	Glass | POE | Cell | POE | Glass
4	Glass | POE | Cell | POE | BIL | POE | Glass
5	Glass | POE | CIL | POE | Cell | POE | BIL | POE | Glass
6	Glass | EVA | Cell | EVA | Glass
7	Glass | Silicone | Cell | Silicone | Glass



And the results of the tests are collective shown in below graphs where the heat release rate is measured for each panel configuration:



Despite a variation in heat release rate all combinations received an indicative fire test rating of B-s1, d0, which indicatively allows for use in buildings with a height up 22 meters. Despite this unified indicative fire test compliance, differences between the various module and material configurations are seen. As expected, glass back sheet modules have a higher heat release rate compared to the glass-glass counterparts, and the addition of a colored interlayer does not seem to change the fire rating. These are important indicative findings that allow them for the use of BIPV facades.

In addition, the consortium has identified a supplier where even better fire rating potentially can be achieved since a silicon encapsulant which is less combustible is used.

Connection concepts of the on-site electrical connecting.

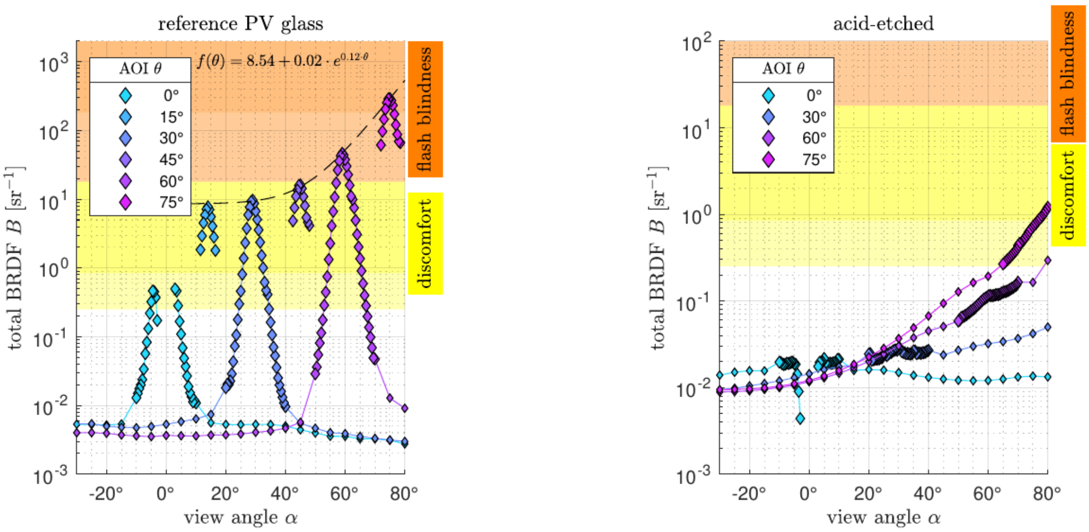
The electrical interconnection of PV modules and optimizers was realized on the inside of the Unit-Sun façade elements, which achieves multiple goals: It separates the steps of mounting the PV modules and electrical installation and interconnection of power optimizers, which allows them to be carried out by technical specialists at separate times. PV modules can either be mounted in the factory or during/after the façade element mounting. It ensures low power and thus minimized electrical hazards during the installation process. By interconnecting power optimizers on the inside, the through-wall connection to modules remains at a low power rating, reducing the need for further electrical insulation and minimizing risk.

The installation and interconnection concept were tested on-site during the installation at DTU's outdoor BIPV test bed (see WP 5), proving its viability and ease-of-use.

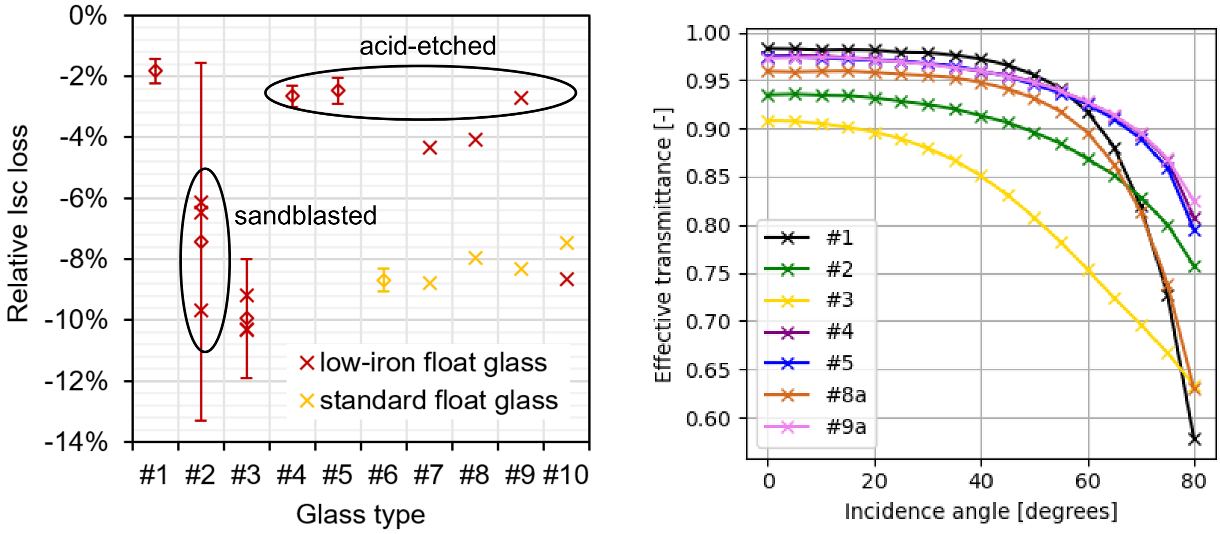
5.3 WP 4: Optical development and characterization

BIPV module designs in sizes appropriate for insulated and ventilated mounting were developed and prototyped at DTU, using common PV encapsulation materials to ensure competitiveness in price. A glass-glass construction was chosen to better comply with fire test ratings (see WP 3) and ensure long reliability. To minimize performance degradation, poly-olefin elastomer (POE) encapsulants are used instead of ethylene-vinyl acetate (EVA) encapsulants, as the latter are known to contribute to corrosion in glass-glass modules, where certain degradation products can be trapped due to the impermeable glass.

A possible barrier for BIPV installations is the risk of reflections from the glass surface causing glare in the surrounding environment. In order to minimize the glare risk for the UnitSun elements, an in-depth characterization of different glass surface treatments (i.e. structuring) was carried out. A method for simplified estimation of the glare risk based on goniometric measurements was developed and applied to several different superstrate candidates, showing the highest reduction in glare risk for satinated (= matte) glass, with lesser benefits for structured glass. In parallel, transmittance measurements were carried out on the different surface structures to determine their effect on performance, showing a <1% loss at normal incidence and effective gains at incidence angles >60°. Results of both investigations were presented at international scientific conferences and published as a journal article in the IEEE Journal of Photovoltaics as well as the WCPEC proceedings.

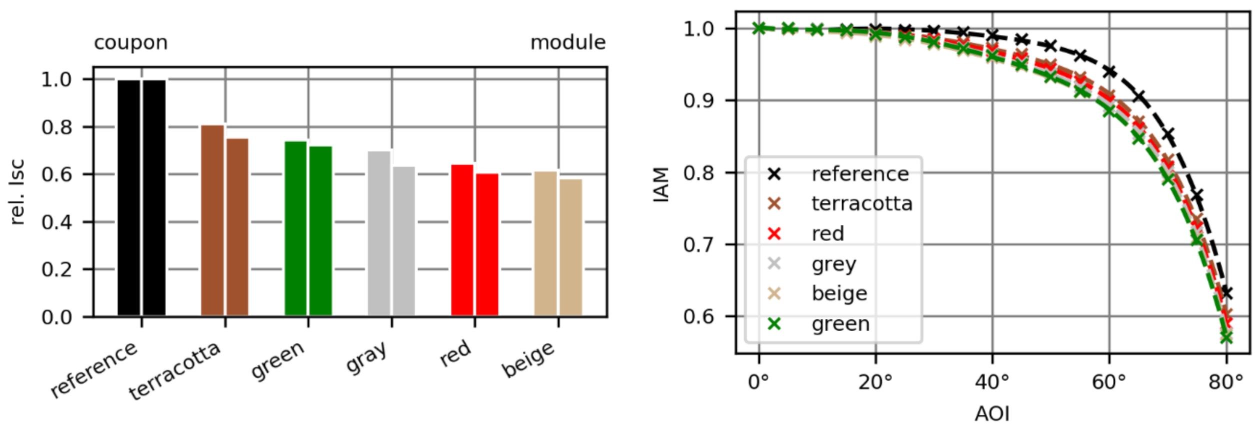


BRDF with discomfort and flash blindness glare limits for a standard PV glass and an acid-etched PV glass (from doi.org/0.1109/JPHOTOV.2022.3189779)



Relative transmittance (Isc loss) for normal incidence and effective transmittance for higher incidence angles (from doi.org/10.4229/WCPEC-82022-3BV.3.10)

In order to achieve a vibrant, homogeneous and angular-independent colour appearance that can be easily applied to different module sizes, coloured interlayers from Solaxess were selected. Prior to system prototyping, optical losses were investigated and transmission losses reported by the interlayer manufacturer verified. With 20-40% transmission losses due to colouration, the products presented reasonable losses while offering the unique advantage of being based on foils that could be easily cut to size. At the time of material selection, no other colouring technologies offering the same flexibility were available on the market, but since then the development of structural pigments has led to both screen-printed ceramic coatings and coloured encapsulants with significantly lower transmission losses being offered on the market. While ceramic coatings do not offer the same flexibility as coloured polymeric layers, as they must be applied to the glass directly, they do allow for the printing of custom designs which are of high interest for architectural integration. In the final phases of the project, contact has been established with Wolbring to provide printed glass as an alternative to coloured interlayers, which can be integrated into PV modules without any modification of the module design and offering lower coloration losses.

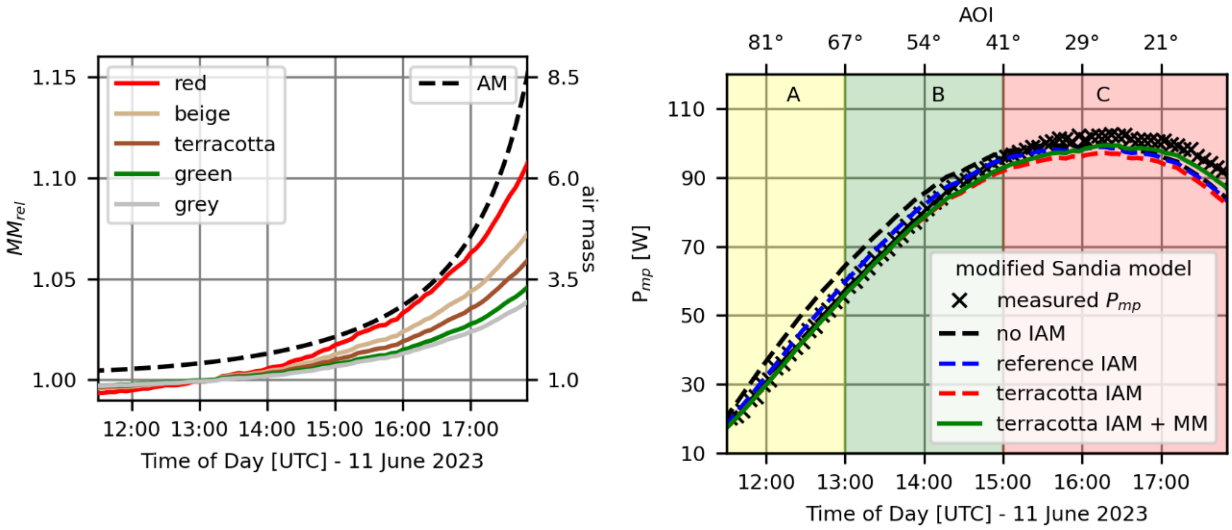


Transmittance losses (relative Isc losses) and incidence angle modifier (IAM) variation between colours (from doi.org/10.4229/EUPVSEC2023/4BO.16.6)

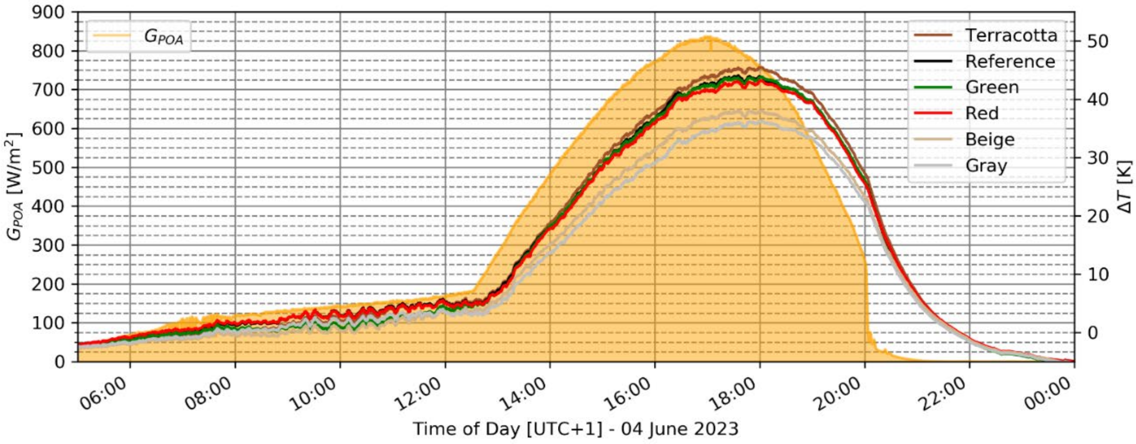
In order to allow for accurate modelling of the BIPV system and its performance, a variety of optical aspects have to be accounted for, which have been investigated using the outdoor test bed (see WP 5) in combination with laboratory measurements of optically equivalent samples. Investigations of the incidence angle modifier (IAM) showed significant variations in angular-dependent reflections between different colours and large deviations to the uncoloured reference. In addition, a large contribution of spectral mismatch gains over the course of a day were detected, based on the spectral response of the differently coloured modules. Especially in the evening, this can lead to spectral mismatch gains exceeding 10% relative to the uncoloured reference. An investigation of the modelling accuracy when neglecting or applying these two loss factors has been carried out, showing significant mismatch between simulated and measured performance when omitting one of these parameters. As many PV performance models do not account for IAM and spectral mismatch effects, this conclusion was also brought to IEA PVPS Task 15, which has caused an activity dedicated to coloured BIPV modelling and characterization to be included in the work plan for phase 3, which started in January 2024.

In terms of thermal modelling, the coloured layers showed to contribute to the thermal energy balance of the BIPV modules through absorption of light not contributing to power production. Light samples (e.g. beige and light gray) showed significantly lower operating temperatures due to their higher reflectance, resulting in higher performance compared to darker colours, which absorb larger portions of the incident light, despite comparable transmission losses. In addition, a significant thermal capacitance was observed for all modules, with no noticeable effect due to colouration.

The influence of coloured layers on both IAM and thermal balance have been presented at EUPVSEC, the main scientific conference for PV in Europe, and published in the EUPVSEC proceedings as well as a journal article in EPS Photovoltaics.



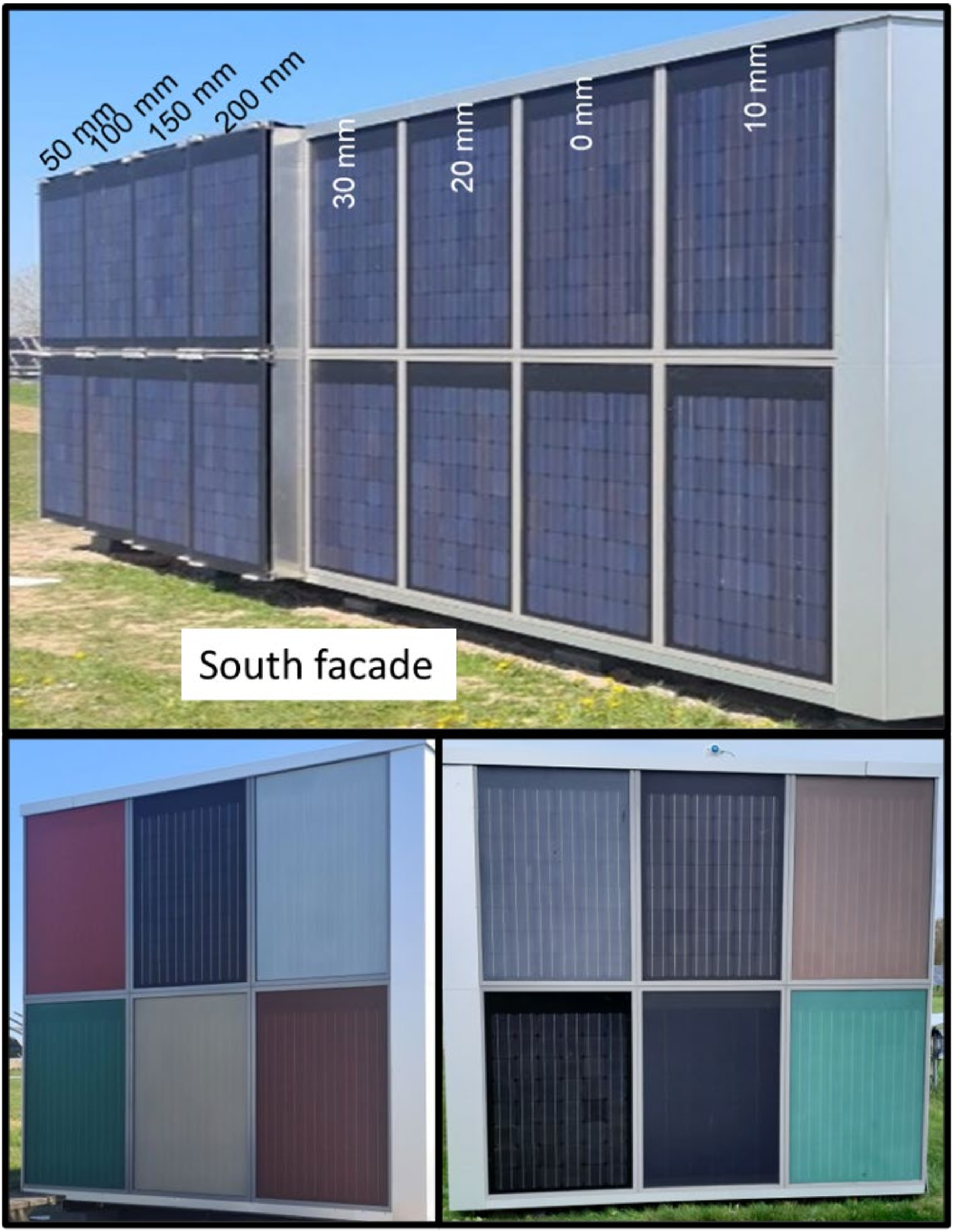
Spectral mismatch gains for different colours and terracotta module modelling accuracy for a clear sky day (from doi.org/10.4229/EUPVSEC2023/4BO.16.6)



Temperature profile over a clear-sky day (from doi.org/10.1051/epjpv/2023028)

5.4 WP 5. Outdoor test bed

A staff container was purchased and the façade was replaced with the Unitsun Elements. The panels were glass-glass modules and as prototypes fabricated at DTU-electro. The staff container was equipped with black panels on the south facade where the airgaps influence on the PV operating temperatures was tested. On the west façade different colored modules were deployed to test the performance on colored BIPV. The East side was mostly used for demonstration where combinations of colored and different ornament glass where used. The panels were equipped with module level performance measurements, 4 wire RTD temperature sensors and in plane irradiance measurements where all data is fed to a database for continuously monitoring.



West facade East facade

The performance related findings have been reported to the stakeholders internally in the group and been published to the scientific community if several peer reviewed papers. One of the major findings is the impact of airgap and the operating temperature on the PV panels. The data from the field shows, that introducing just a small airgap can reduces the temperature rise of the PV modules by approximately one third, and a further increase in the airgap will lead to further reductions:

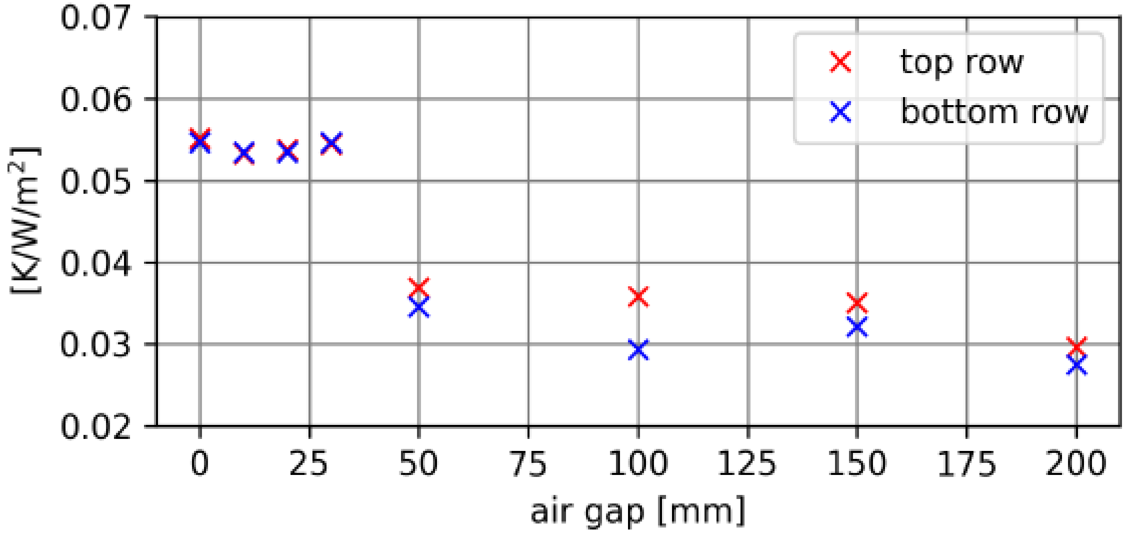


Figure 5: Temperature coefficient of the various airgap configurations. The 0-30mm airgap is for a nonventilated cavity behind the module, whereas the remaining airgaps is for free ventilation behind the modules. The graph should be read that at STC (~maximum irradiance conditions) the temperature rise of the PV modules is around 1000* the coefficient, such that the nonventilated configurations is expected to have a temperature rise of up to 55 K at maximum irradiance, where as it is only 30-35 K for the ventilated cases, all references to ambient temperature.

Further energy yield analysis shows that that the DC energy provided by the panels is comparable to non BIPV configurations, and the introduction of an airgap increases the energy harvest by around 5% P/A, owing to the lower temperature.

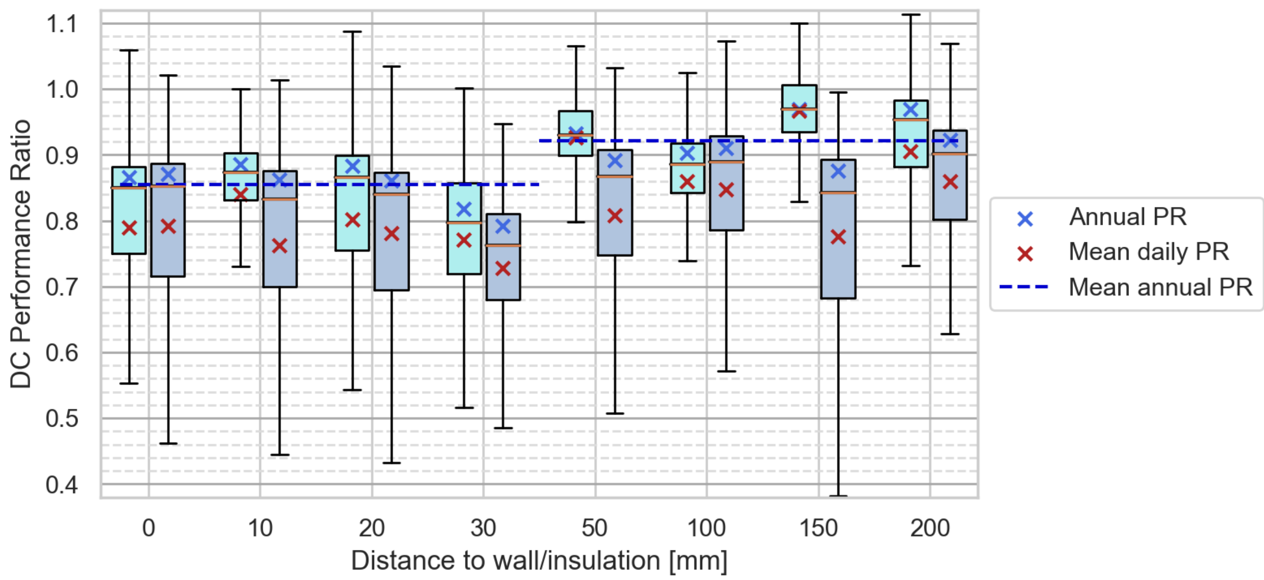


Figure 6: DC performance ratio of the configurations, for the nonventilated configurations the thermal losses are high and therefore the yield is lower.

Details on the performance on colored BIPV has also been published

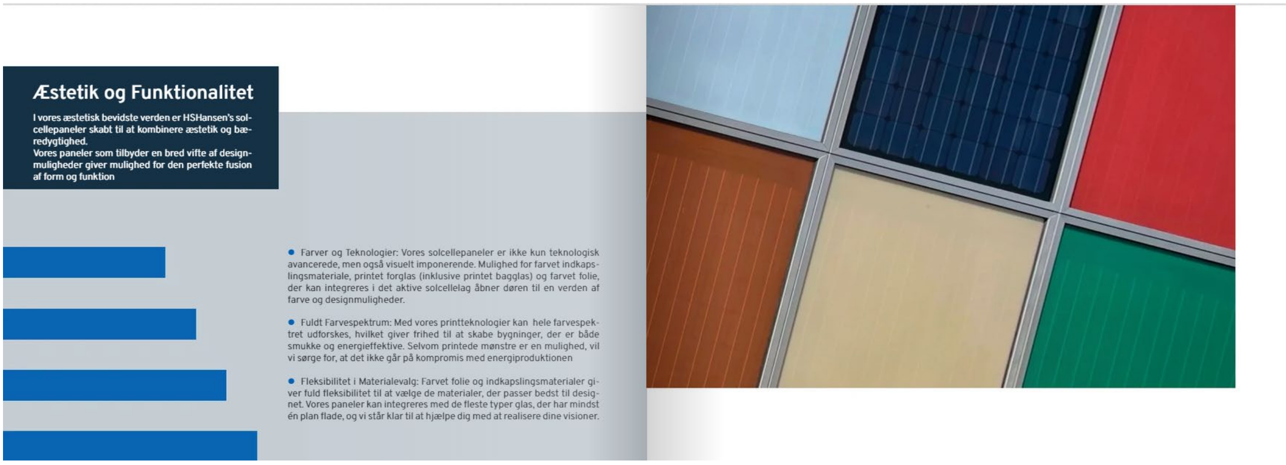
5.5 WP6 Demonstration

As described earlier, it was not possible to demonstrate the solution in a full scale building even though the solution was written into 5 tenders and an ongoing building process was also approached. The major challenge was fire safety not being class A even though living up to Class B is highly impressive when compared with the BIPV industry's other products.

The sales material financed by HSHansen was though possible to be realized by based on the test facility described above.

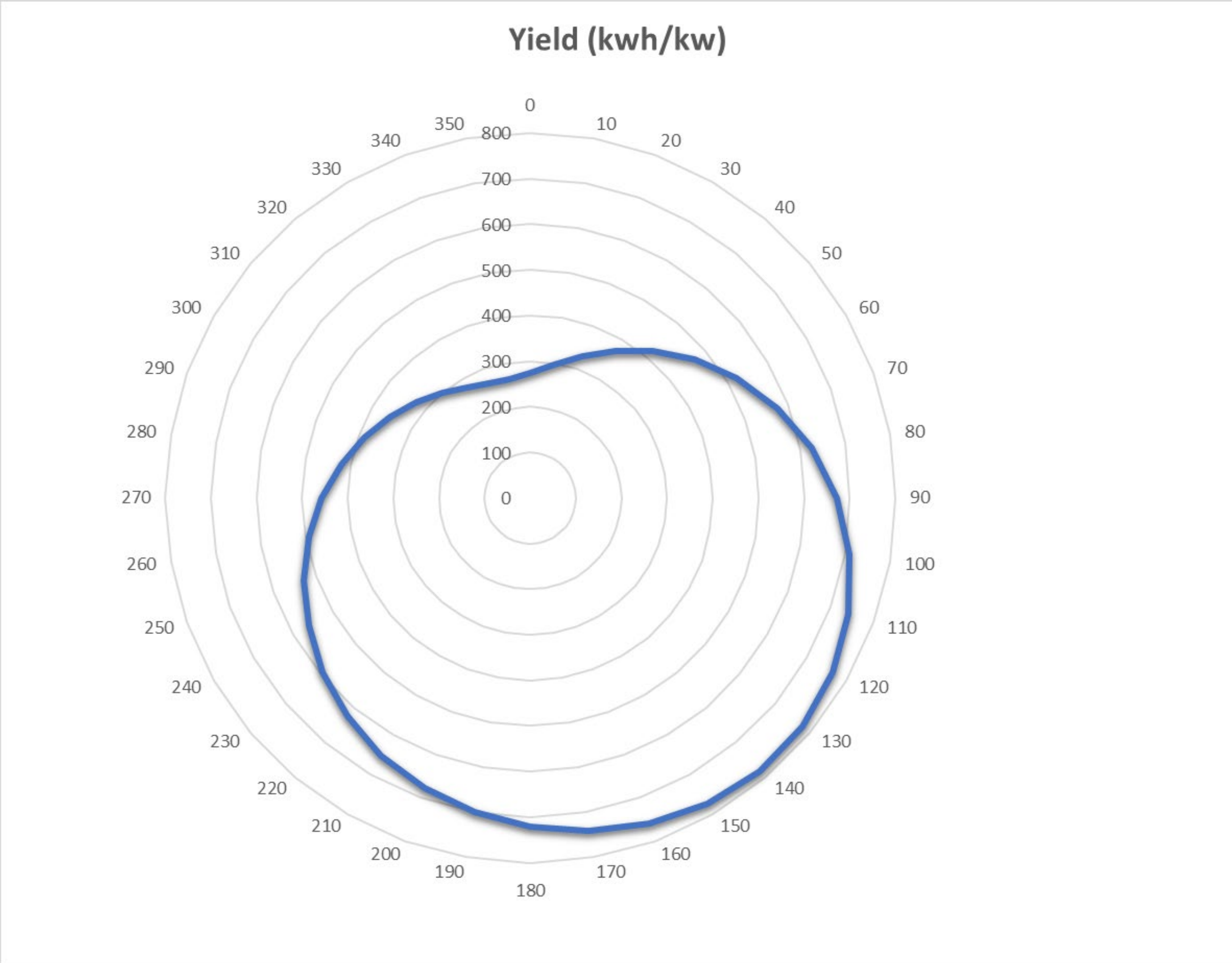
5.6 WP7: Visualization and yield estimation tools supporting deployment

Appearance catalogue was realized as part of the marketing tool for HSHansen. An interactive flyer was made available:



An energy estimation prediction tool was developed for the sales department of HS Hansen. It was developed to quickly estimate the energy output for a potential building based on knowledge on surface orientation and choice of color, at was well received in the sales department of HS hansen.

The output and simple user interface is shown in below figures.



	Input	Beregnings resultat						
Facade nummer	Facade areal (m2)	Solcelle dækningsgrad (%)	Orientering (grader, syd=180)	Farve valg (%)	Farve Transmi	Installeret effekt (KWp)	Energi yield (Kwh/KWP)	Årlig energi (KWh)
1	100	80%	180	Black	100%	16	721,558	11545
2	200	60%	90	White	55%	7,26	670,89	4870,6614
3	200	60%	270	Terracotta	82%	16,1376	456,636	7369,009114
4					#N/A	#N/A	0	#N/A
5					#N/A	#N/A	0	#N/A
6					#N/A	#N/A	0	#N/A
7					#N/A	#N/A	0	#N/A
8					#N/A	#N/A	0	#N/A
9					#N/A	#N/A	0	#N/A
10					#N/A	#N/A	0	#N/A
11					#N/A	#N/A	0	#N/A
12					#N/A	#N/A	0	#N/A
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18					#N/A	#N/A	0	#N/A
19					#N/A	#N/A	0	#N/A
20					#N/A	#N/A	0	#N/A
Totalt	500	0,666666667				39,3976		23785

Dissemination

The project has been the basis of the following research publications and contributions to research conferences.

1. Babin, M, Jóhannsson, IH, Jakobsen, ML & Thorsteinsson, S 2023, 'Experimental evaluation of the impact of pigment-based colored interlayers on the temperature of BIPV modules', EPJ Photovoltaics, vol. 14, 34. https://doi.org/10.1051/epjpv/2023028
2. Bertomeu i Baldé, A, Babin, M, Andersen, NL & Thorsteinsson, S 2023, IAM Losses in Colored BIPV: From the Lab to the Field. in Proceedings of 40th European Photovoltaic Solar Energy Conference and Exhibition., 020289, EU PVSEC, 40th European Photovoltaic Solar Energy Conference and Exhibition, Lisbon, Portugal, 17/09/2023. https://doi.org/10.4229/EUPVSEC2023/4BO.16.6
3. Babin, M, Thorsteinsson, S, Santamaria Lancia, AA, Poulsen, PB, Thorseth, A, Dam-Hansen, C & Jakobsen, ML 2022, Dependency of IAM Losses in Colored BIPV Products on the Refractive Index of Colorants. in Proceedings of 38th European Photovoltaic Solar Energy Conference and Exhibition. EU PVSEC, pp. 583 - 588, 38th European Photovoltaic Solar Energy Conference and Exhibition, Lisbon, Portugal, 06/09/2021. https://doi.org/10.4229/EUPVSEC20212021-4BO.4.2
4. Babin, M, Thorsteinsson, S, Jakobsen, ML & Spataru, SV 2022, 'Glare potential evaluation of structured PV glass based on gonioreflectometry', IEEE Journal of Photovoltaics, vol. 12, no. 6, pp. 1314 - 1318.

6. Utilisation of project results

The findings in the UnitSun project will be carried forward by HSHansen where the curtain wall market is increasingly leaning towards active facades. Though a demonstrator project would have been helpful, the findings in the UnitSun project process has created a better understanding of what options are available in regard to colours, power electronics and supply chains. HSHansen has an ongoing dialogue with market leaders and stake holders and with the UnitSun resource, the conversation with architects can be more precise to develop better solutions.

The models showing expected yields makes for a more convincing product presentation for customers, together with the angle dependency research performed in the UnitSun project. These models will be utilised as groundwork for a more data driven approach, where modern power electronics offer possibilities for data collection to optimise both existing projects where system updates can be implemented to increase both customer value and a create a persisting value for realised projects for HSHansen as well as providing a possible edge in market tenders and customer conversations to both gain market shares and to cultivate new markets. Analysing the data obtained from the power electronics used in the UnitSun project is expected to move HSHansen's market position forward as projects are realised and data is obtained.

The market situation for active facades is by HSHansens experience on the brink of a breakthrough. In few inquiries are active facades not mentioned but the obstacles have often been of technical or architectural nature and with UnitSun some of these obstacles have been addressed thoroughly.

For the end customer local energy production is an important feature that allows for more flexibility for meeting building codes and CSR objectives as a contributor to reducing the carbon footprint. With UnitSun as a curtain wall product, building on HSHansen's UnitAl platform with minimal on-site installation work, the aim of making active facades easily available to the market has taken a step forward and the expectations to the UnitSun product are high as the product matures as well as the regulations by EU will make an active building envelope more or less mandatory. Players in today's construction market has an increasing expectation that suppliers have products and knowledge about active products and to meet these new market expectations HSHansen are upgrading staff with employees who have experience with renewables to diversify the in house capabilities and resources as well as establishing new collaborations with suppliers to improve solutions for customers.

One aspect of façade construction that is inevitable is fire safety and in regards of UnitSun this will be a focus point for HSHansen going forward. To the project group's knowledge there are currently no PV products on the market that can obtain a class A fire safety certification, and this proves to be a major obstacle. A class A fire safety certification is a prequalification as a building product, where little to no further documentation is needed for implementing the product in the building envelope and it is especially in façade construction a major focus point. If class A is not achieved there will need to be further documentation provided case by case and it has been an obstacle for making the demonstrator for the UnitSun project. It is particularly difficult to offer these active products in projects where response time is very short. The short time from inquiry to delivery, as is often seen as solutions change during projects, the demand for documentation is seen to make products without a class A certification not viable. After conversations with market participants the issue is being addressed and first prototypes are expected in 2025 and HSHansen will meanwhile pursue possible solutions to the issue, already having conversations with the UnitSun project group about how to proceed.

The RePower Europe initiative will spill into all the member countries demand for solution in the end of the decade and the UnitSun product will be key here. So time is working for the UnitSun solution.

The UnitSun project has cofinanced a PhD student who have worked intensively on the project and have therefore also been able to ensure several scientific dissemination products have been realized about the project to the PV research community.

7. Project conclusion and perspective

The UnitSun project has successfully developed a Building Integrated Photovoltaics version of the HSHansen UnitAL prefabricated façade system. The project met its technical milestones, demonstrating the integration of solar cells into façade systems with aesthetic flexibility and optimized performance. Key achievements include the development of fire-resistant BIPV modules, the establishment of an efficient electrical system with minimal on-site assembly, and the realization of a market-ready appearance catalogue and energy yield simulation tools.

Despite these successes, the project faced challenges in achieving the highest fire safety standards, which impacted the ability to perform a full-scale 1:1 installation. Nevertheless, the project has significantly advanced the understanding and application of BIPV systems, positioning UnitSun as a competitive solution for future market demands.

Next Steps for Developed Technology

The next steps involve refining the UnitSun technology to overcome the remaining fire safety challenges and achieving higher fire resistance ratings. HSHansen will continue to enhance the BIPV modules, focusing on obtaining a Class A fire safety certification if possible. Additionally, efforts will be made to streamline the integration process, making the system more accessible and attractive to the construction market.

Further development will also include expanding the application of the energy yield simulation tools and appearance catalogues, which have proven to be valuable for marketing and client engagement. Continuous collaboration with industry stakeholders and ongoing dialogue with market leaders will be crucial to adapting the technology to meet evolving standards and customer needs.

Perspective on Future Development

The results of the UnitSun project have the potential to significantly influence the future of BIPV systems. As regulations increasingly mandate the integration of photovoltaics in building façades, the UnitSun technology is well-positioned to meet these requirements. The innovative solutions developed in this project, such as the fire-resistant BIPV modules and efficient electrical systems, set a new standard for the industry.

Looking ahead, the UnitSun project aligns with the EU's RePower initiative, which will drive the adoption of renewable energy technologies in buildings. By addressing the current market barriers and advancing the technology, UnitSun can play a pivotal role in the widespread adoption of active façades, contributing to sustainable building practices and energy efficiency.

The knowledge gained from this project will not only benefit HSHansen but also the broader industry, as it highlights the importance of integrating photovoltaics into building designs. The continued focus on innovation and collaboration will ensure that UnitSun remains at the forefront of the BIPV market, paving the way for future advancements and applications.

8. Appendices

Add link to relevant documents, publications, home pages etc.