Final report

1. Project details

Project title	iROOF Heltagsløsninger til bygningsintegration af solceller
File no.	J.nr. 1936-0013
Name of the funding scheme	EUDP 2013-Særpulje
Project managing company / institution	henrik-innovation ApS
CVR number (central business register)	25044045
Project partners	1. henrik-innovation ApS 2. BlueCity A/S 3. Vitral A/S 4. ProSolar (BlueCells) A/S 5. Holscher Design A/S 6. Vandkunsten A/S 7. GreenWays 8. Steensen & Varming ApS 9. Atopia ApS 10. iROOF Solar ApS
Submission date	12 February 2021

2. Summary

The objective of the iROOF-project was to develop a system for building integration of standard rectangular solar panels for pitched roofs. The system is designed to adapt to different widths and heights of the roof and provide an aesthetical solutions covering the whole roof, and at the same time provide good ventilation of the backside of the solar cells to maximize the power production.

The system only has 5 components and does not require any altering of the standard framed solar panels. The panels are mounted in the system as clinker-built, which creates an appealing visual effect more attractive to traditional constructions of BIPV which large surfaces without any contrast or texture.

The mounting system was tested against a traditional BIPV-system documenting the good ventilation properties of the iROOF-system and a full scale pilot installation on Uldum Højskole was realized with success.

Formålet med iROOF-projektet var at udvikle et system til bygningsintegration af standard rektangulære solcellepaneler til tage med hældning, som kan tilpasses varierende tagstørrelser og give en æstetisk smuk løsning, som dækker hele taget og som samtidig giver en god afkøling af solcellerne og derved maksimerer den elektriske ydelse.

Systemet blev designet så det med 5 enkle profiler og uden behov for tilpasning af nogen art for solcellerne, giver en opbygning på taget i klink, som derved også arkitektonisk bryder de bare glatte flader, som er vanskelige at integrere med traditionel bygningsdesign.

Det udviklede system blev testet sammen med et traditionelt system og effekten af afkølingen demonstreret og et fuld-skala pilot anlæg på Uldum Højskole blev installeret, som dokumenterer funktion og ydelse.

3. Project objectives

The development of good mounting systems for building integration of photovoltaic panels (BIPV) has been a key challenge since the first mounting of solar panels on pitched roofs. The technical development has been relatively slow and many unsolved problems remains to be solved re. construction details, architecturally appealing solutions and cost-benefit of the whole solution. The development of mounting systems is ongoing in many countries, each characterized by national building standards and traditions and often with the challenge to unite long construction traditions and the high tech of solar panels.

The objective of the iRoof project is to challenge the way the industry often thinks about BIPV through the development of a whole roof system, which fulfills all criteria for the construction details for the surface of the roof and the climate envelope and is designed to maximize the power yield of the system under all climate conditions. The system is developed to be utilized for all types of standard rectangular edge protected solar

panels, not requiring any custom-made solutions for the panels and thereby keeping the cost of the solar panel itself to a minimum.

In the project also the various solutions and principle of optimization of total cost of ownership is addressed, based on Danish conditions for metering, prioritization of local use of the electricity produced and awareness of the user to prioritize energy demanding tasks at the time where solar energy is available.

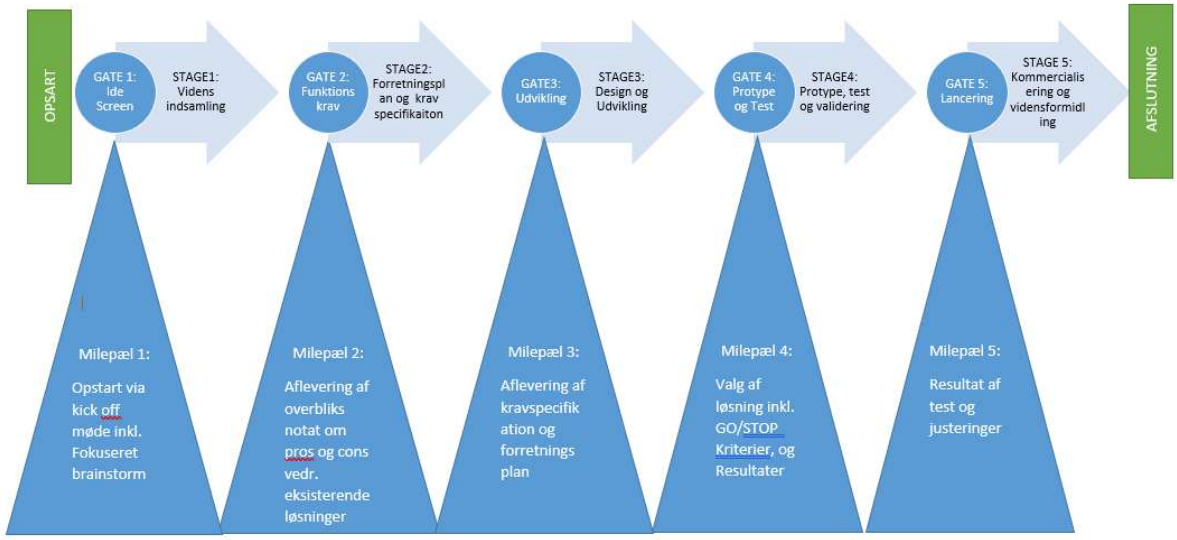
The mounting system has been tested in prototypes, documenting the cooling effect and increased yield of solar power from the panels mounted in the iROOF system, compared to a standard, non-ventilated roof integration. A pilot installation of the complete system was carried out at Uldum Højskole and has been in continuous operation since 2016.

4. Project implementation

The project was organized in 6 work packages:

1. Design
2. Electrical concept
3. Economy and financing
4. Authorities and legal issues
5. Business plan
6. Dissemination / focus group

To monitor and prioritize the project progress of the project, the management of the project was organized in a stage-gate structure with the following stages and gates:



Stage 1: State of the art in the market
Stage 2: Design Brief and business plan
Stage 3 Design and Development
Stage 4: Prototype, test and evaluation
Stage 5: Commercialisation and dissemination of the results

From stage to stage the gates were defined as control mechanisms to ensure that all the knowledge and decisions where elaborated before continuation to the next phase. In practice it was not possible to strictly follow the stage-gate structure and some incidents of iteration occurred, but as overall tool to create a common awareness of the state and progress of the project, it was found very useful.

In weighting of the budget allocation focus was on the design and the technical development and testing, and to a smaller extent on the national tariffs, structure, international aspects and general business plans.

The project followed the anticipated process outlined in the proposal and contract. In the course of the project, the project team was able to advance the design very rapidly and when already the first attempt to prove the efficient cooling of the panels was successful the level of the design was advanced to a level, where the full-scale demonstration of the system would make sense ass the next step. It was agreed with EUDP to prioritize the remaining to budget to facilitate a full scale pilot installation which was realized at Uldum Højskole in 2016, where the system has been in operation and has proved the concept.

A couple of key decisions and challenges were identified and solved, but for further development these would be the issues to address to achieve the basis for a commercialization of the results.

The system developed provide a complete system meeting all objectives in the design brief developed, but it still needs a secondary roof underneath to provide the full protection of the building for rain and snow. In the development the team agreed, that for the time being, the only secure solution would be a full secondary roof underneath, but this could also be realized using foils or similar known from the traditional construction of roofs. The reason to prioritize a full secondary roof was to match the durability of the solar cells and mounting system, which is longer than the foils and polymers usually used for secondary roofs. Technically there is no doubt that the solid secondary roof is the most durable, but this also means that the cost of the total system will be higher than solutions where the secondary roof can be designed using foils or similar.

In the design process of the mounting system, effort was made to provide as simple a geometry as possible, but still the manufacturing costs at Danish manufacturers turned out to be prohibitive for a direct commercialization of the results. For various reasons the design team has not been able to pursue this further, but strategies for placing the production at either more automized manufacturing facilities and/or looking more internationally for potential manufacturing partners would be the natural next step towards launching the product in the market.

5. Project results

All the key objectives of the project were met in the project and within the budget the team even managed to realize a full-scale pilot installation of the system developed. Available now are detailed drawings and specifications for the mounting system, which using only 5 standard components can adapt any standard solar panels to various shaped pitched roofs.

Part of the results where also the documentation of the ventilation efficiency of the developed system, compared to a traditional non-ventilated BIPV system. The drawback however is economically, where the iROOF system require a solid secondary roof, which is not always the case for other BIPV-systems.

In short all the technical and aesthetical objectives where met, but before a full commercialization can be realized, an optimization process including optimization of manufacturing costs need to take place. However the potential seems promising but will require the involvement of partners outside the original project team.

After inauguration of the pilot installation at Uldum Højskole, the project team received many positive reactions, but the stipulated end-user price of the system at the current level remains prohibitive for commercialization.

In terms of market the iROOF-system has a very large technical potential, since it addresses the huge need for integration and mounting systems that can bridge the challenges of a fixed geometry of an existing building and the fixed geometry of standard solar panels into a fully integrated and aesthetically attractive solution.

The results of the projects has been presented at several seminars by EUDP, Solar City Copenhagen and referenced in various magazines in the building sector.

6. Utilisation of project results

At the current stage, no immediate plans for commercialization of the project results are being put into action due to lack of funding among the partners to invest in this. However, the plans are relatively simple, since all technical issues seems to be solved at a high level of confidence and the results of all experiments and full scale pilot installation served as proof of concept.

The next steps towards the market will include efforts to reduce the manufacturing costs of the system components and testing of less costly solutions for the secondary roof. Many systems for secondary roofing exist on the market and it would be relatively simple to set-up a mockup to investigate whether these systems would

be sufficient as secondary roof for the iROOF system. If this turns out successful the market potential opens immediately internationally, because the iROOF system will be a direct and more competitive alternative using standard solar panels that many other bespoke systems, which demands special solutions from the solar panel manufacturers.

On a policy level iROOF could be a very interesting solution for the roll-out of the green investments anticipated the coming years, which will need investments in the existing building stock. Combinations with improvement of the building envelope and renovation projects including the need to change the roofing, would provide an interesting market for iROOF, where the extra investment would only be mounting system and solar panels and not including the secondary roof, being compared to other roofing materials, not having an energy production.

The project team agreed not to invest in protection of IPR at this stage, because the possibility to copy the inventions made and just add a few other details would be very hard to challenge in practice. In the project several manufacturing aspects where addressed and it is very likely that in the process of commercialization the IPR-efforts will be targeted the manufacturing process in stead of the design itself.

7. Project conclusion and perspective

ect has proved that with only a very few carefully designed components it is possible to make a very attractive integration of standard solar panels to pitched roofs, providing high power yields due to efficient ventilation of the panels and covering the full area of the roof, with a clinker build appearance.

Alle key technological challenges set out in the project has been solved to a level where the remaining barrier for commercialization is all about optimization of manufacturing costs. The architectural and aesthetical potential of the iROOF system is quite unique and provide a very appealing alternative to most other BIPV-solutions where the pitched roofs of existing building are converted to flat reflecting surfaces which often is in contrast to the rest of the architecture of the building.

The project results address the market for BIPV internationally and the next step to commercialize the project results will rely on identifying and set up collaboration with commercial partners, who can scale the production and have the sufficient financial power to push the product to the market.

8. Appendices

Due to the on-going activities to commercialize the developed system, technical details and further information is available on demand on the condition of signing a non-disclosure agreement.

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