Final report - PRoof

1.1 Project details

Project title	PRoof
Project identification (program abbrev. and file)	64015-0099
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	Innogie ApS Thrigesvej 23 7430 Ikast
Project partners	Cenergia Brdr. Paulsen
CVR (central business register)	3314 8879
Date for submission	

1.2 Short description of project objective and results

1.2.1 Dansk version

PRoof havde til formål at udvikle et æstetisk flot tagløsning der kan dække det årlige forbrug af elektricitet og varme. Projektet har i alt sin enkelthed bestået i at udvikle en solcelle (PV) tagløsning til at producere elektricitet og indarbejde en termisk absorber (T) til opvarmning. Selve PV-delen af projektet har været utroligt succesfuldt og har i projektperioden vundet flere priser, Danish Design awards 2016 og iF Awards 2017. Den termiske del har ved fuld testinstallationen i projektet ikke bestået de standarder for stresstest som ønskes, hvorfor denne del kræver yderligere forskning og udvikling for at kunne komme til kommercialiseringsstadie.

1.2.2 English version

The aim of PRoof is to develop an aesthetic pleasing roofing solution which covers the annual need of heat and electricity for a household. The projects includes development of photovoltaic (PV) to produces electricity and thermal absorbers (T) production of heat. The PV part of the project has been very successful by winning awards under the project, Danish Design Awards 2016 and iF Awards 2017. The thermal part has not passed the standards under test on full installation. The thermal part needs further research and development to reach commercialisation stage.

1.3 Executive summary

The PRoof project on the PV part has been very successful with two prestigious design awards, Danish Design Awards 2016 and iF Design Awards 2017. The management took this golden opportunity to the the PV Roofing System into the commercialisation stage and market launch the product in november 2016 at Building Green Fair in Forum, Copenhagen. The PV Roofing

System has been patented to secure the IPR and a new business plan has been made. In cases of renovating the roof of a 70s house it will secure the house owner approx. 70% of the yearly consumption of electricity and heat given that the house is electrically heated. The ambition is to reach full cover of the heat and electricity consumption and the Thermal absorbers is a vital part of that ambition.

There were several theoretical tests and 3D simulations to determine the correct material for the thermal absorbers. In particular certain materials performed very promising at the 3D simulation, but eventually did not pass the stress test at real life test. The initial results during the wintertime show great output of heat.
The calculations are made on 10 meters, which result in 202W, because the temperature inside the tube is increasing through every meter of the concept. When there are 23 rows of solar panels, then there are 22 channels between, which give a total energy outcome on 202$*$ 22=4450W.

1.4 Project objectives

The aim of the project is to develop an aesthetic pleasing roofing solution which covers the annual need of heat and electricity for a household or apartment complex. The milestones in the project have been defined as:

- M1 System specification
- M2 PVT Integration in roof
- M3 Installation full scale

- CM1 Updated Business plan

M1 System specification was delivered as expected with a vision of a photovoltaic (PV) roofing solution as the core product where the customers can add-on thermal (T) absorbers, heat pump or battery. The project would only focus on PVT and standard heat pumps and battery will be used for the final solution.

M2 PVT Integration in roof was separated in two steps: the PV part which should be the core product and T part that should be an add-on function. The development of the PV was very successful and Innogie was winning the Danish Design Awards 2016. The management of Innogie decided the PV Roofing solution could be commercialised without the T part in the first place. That decision delayed the development of the T part of the project and all resources was used to prepare the PV roofing solution for market launch. At Building Green 2016 in Forum, Copenhagen the PV Roofing solution was market launched and focus to finish the T part of the project could start.

The milestone M3 Installation full scale has a really bad start, as the original test house owner decided to pull out the agreement, because the PVT installation would mean a new roof construction. The test customer was not prepared to make those changes for his own expenses. The project was delayed to find a new test house, which was a little bit bigger than the original. The completion on the full scale construction of the PVT went fine, but the following test

results on the T part did not turn out as expected. Therefor the T part is not ready for commercialisation and further research and development is needed.

1.5 Project results and dissemination of results

1.5.1 PV Roofing solution

The PV roofing solution was transformed from the existing project, Solaro with solar tubes under “Fornyelsesfonden” into a full functional PV Roofing system.



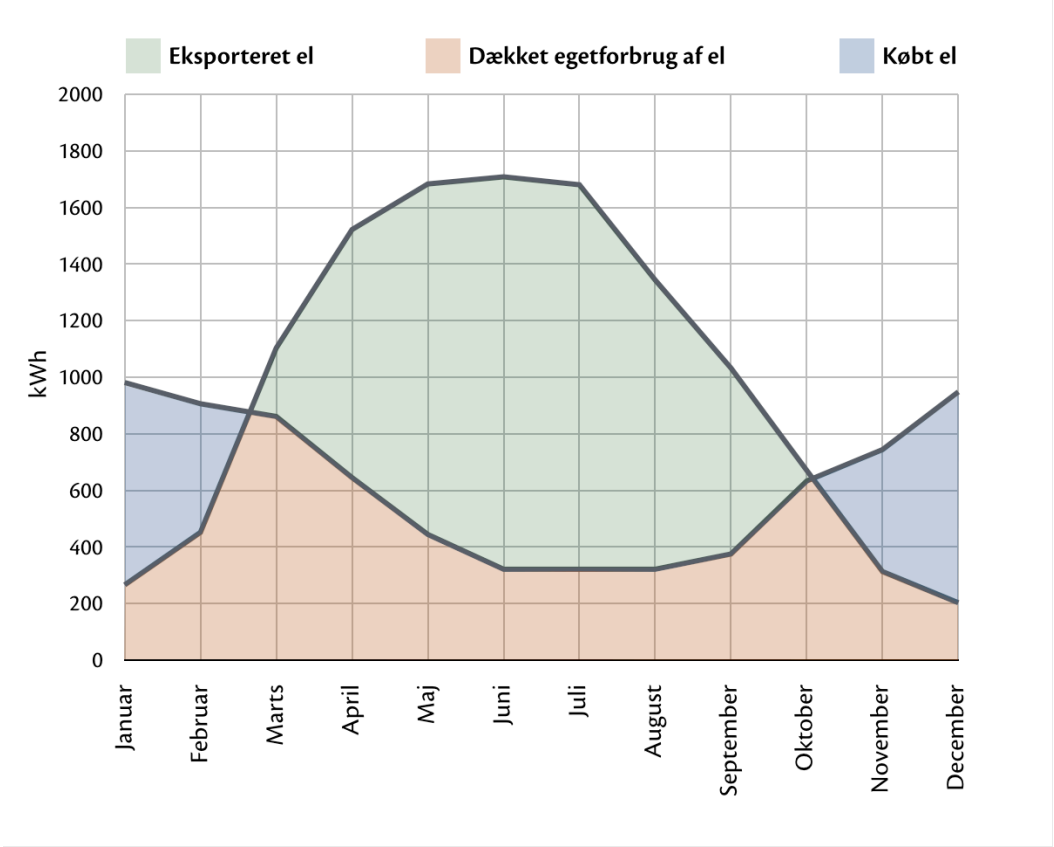
The results were very promising and in the early stage the PV Roofing solution awarded by Danish Design in April 2016. That was a golden opportunity that the management of Innogie could not pass. The PV solution has applied for patent for the design solution, to secure the IPR. Al resources were used to put PV Roofing Solution on market, when the award was still counting. In the beginning of 2017 the PV roofing solution also won the prestigious iF Design Awards.

DANISH DESIGN AWARD WINNER 2016

iF DESIGN AWARD 2017

CASE: PV Roofing solution at Heimdalsvej, Haderslev (not incl. in this project)

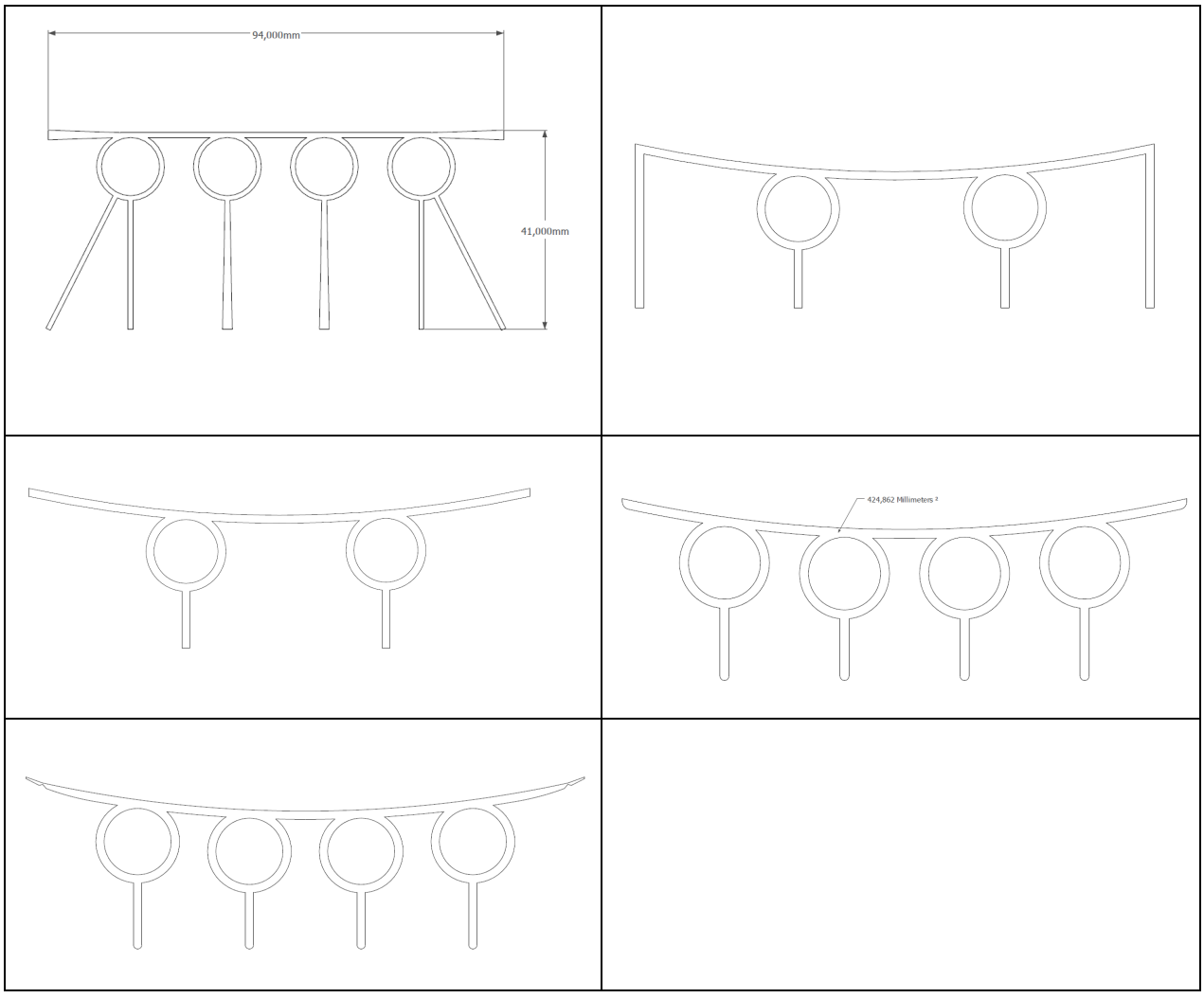
Renovation of a 1970s roof on 145 m2 building covers 70 % of all power consumption. The additional cost for PV part compared to traditional roofing surface has an expected payback time on 10 years. With the full roof cost a payback time on 20 years is expected.



1.5.2 Thermal Absorber

The development of the T part was made with several designs and 3D simulations.

Requirements	
1. Minimize material usage	
2. Maximize energy outcome (thermal conductivity)	
3. Make room for cutting tool	
4. Must be mounted from above	
5. Must be UV resistant	
6. Avoid icing on the back of the roof	
7. Make room for the screws	
8. Make the solution affordable (think about the usage of materials)	
Specifications	
Temperature area	−25℃−+75℃
Lifetime	20 years or more
Geometry	Within 95mm*40mm
Price	Within 5% of nearest competitor



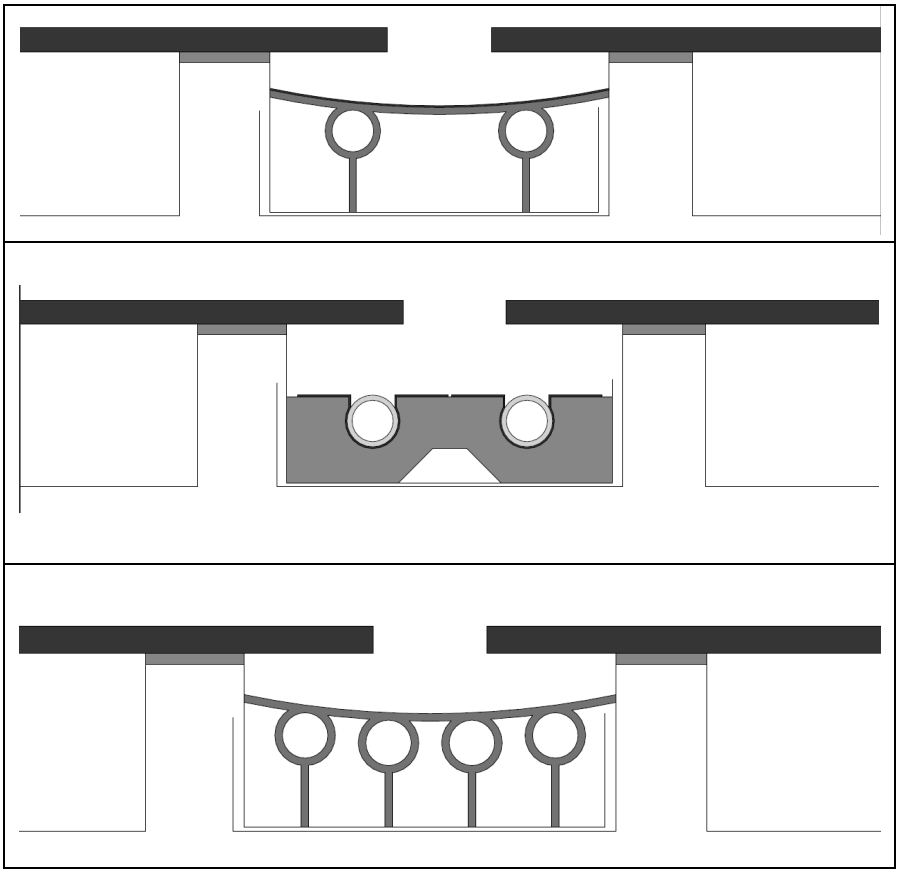
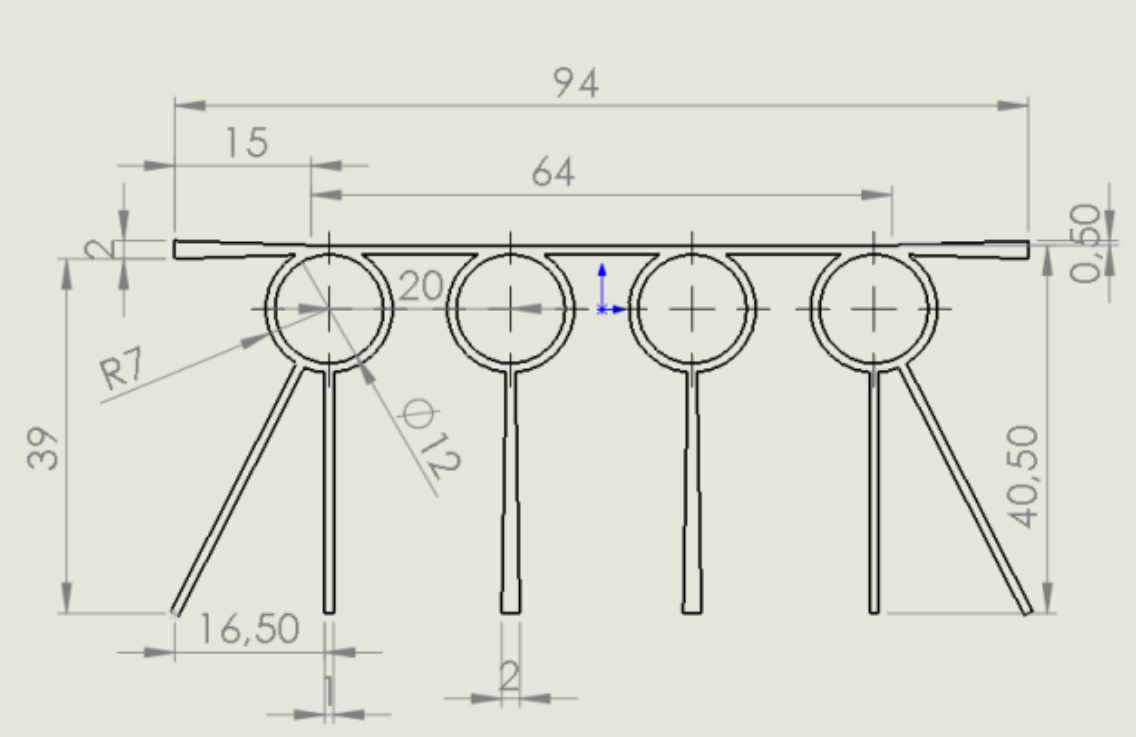


Figure 1 - small test with 3D print

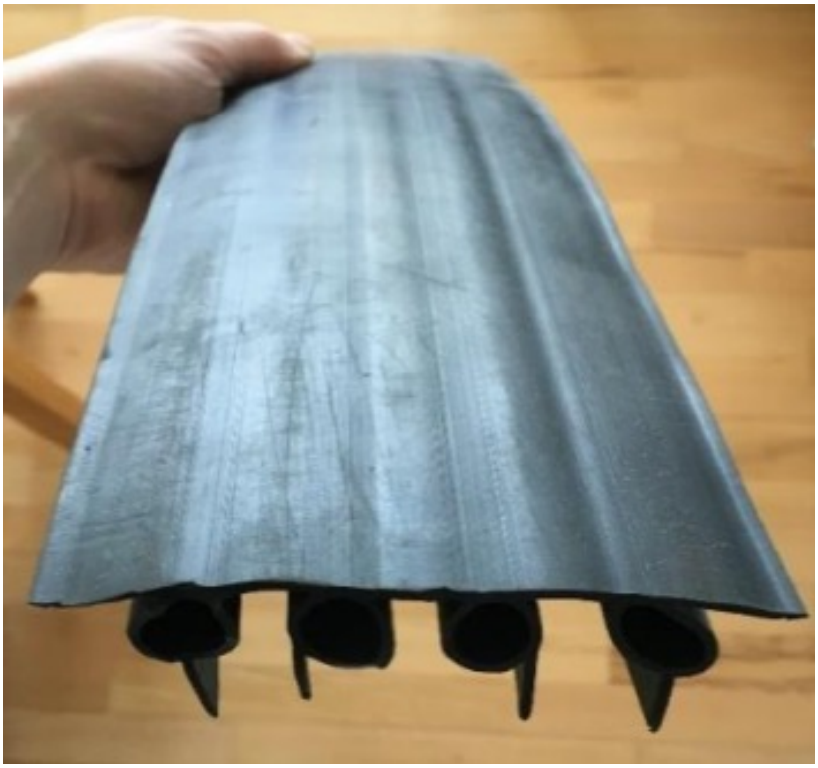
The chosen concept is further studied to find different ways to optimize the energy outcome, which led to the following model.



Simulations show that the final concept has an energy outcome at 27,7W for one meter. There is also made an example where the size of a test house is used, which have 23 rows of solar panels, where there are 9 solar panels in every row. Every solar panel is 1,2 meter and therefore 1,2$*$ 9=10,8 m in total, and to give the product some room for the material to expand calculations are made on 10 meters.

This result in 202W, for every row, because the temperature inside the tube is increasing through every meter of the concept. When there are 23 rows of solar panels, then there are 22 channels between, which give a total energy outcome on 202$*$ 22=4450W. These calculations are based on a normal winter day in Denmark, and extremes are not taken into considerations.

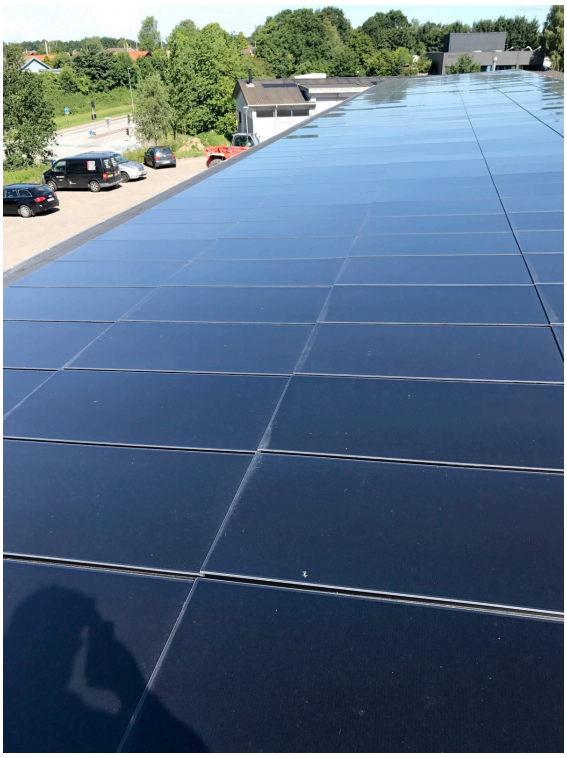
The average energy outcome pr. meter on this house is then 20210=20W/m, which is comparable with the general ground heating solution where the energy outcome is about 11,5W/m – 23,3W/m. The general ground heating solution is where the tubes are spread out on a large area in the depth of one or two meters under the ground. Another opportunity is the ground heating solution where the tubes are drilled 23m – 91m into the ground, which give a larger energy output on 19,2W–55,5W. This initial work has been the first step in a plan that Innogie has made to develop the thermal absorbers.



1.5.3 Installation full size

The new test site was found at Norgesvej, Haderslev. The installation for PV Roofing System was perfectly matching the criteria of the project. Several tests and stress tests with the thermal absorber did not pass the requirements. Therefore the thermal absorber needs to be evaluated before further research and development can take the technology into commercialisation stage.

When pressure was added to the system, the material became unstable and eventually punctured. Therefore further test on the material and close cooperation with the existing supplier could solve the problems. Other suppliers could be tested as well, before new research and development of the thermal absorbers should begin. The supplier is currently doing internal testing of the material types.



1.5.4 Dissemination

The project has been well exposed at:

- “temadage for Solar City” in Sønderborg and Copenhagen
- Erhvervsakadamiet Lillebælt in Odense
- Building Green Exhibition in Copenhagen

Winning awards at Danish Design Awards and iF Design Awards have given the project a lot of publicity.

1.5.5 Turnover, exports and employment

The results of the project at current stage and expected results in 3 years

	2017	2018-2019	2020-2022
Employment	2	10	25
Turnover	<1 mil DKK	15 mil DKK	55 mil DKK
Export	0	5 mil DKK	35 mil DKK

1.6 Utilization of project results

The results of the project have already been taken into commercialisation stage at the PV part of the project. Innogie has made patent on the PV Roofing System. Both Innogie and Tømrerfirmaet Paulsen is a part of the commercialisation stage while Innogie is selling PV Roofing Systems and Tømrerfirmaet Paulsen is installing. The new business plan for the PV part

has been updated and tried executed doing 2017 while finishing the thermal absorber at the PRoof project.

The market for Building Integrated Photovoltaic (BIPV) products is interesting especially in EU where the new rules of Nearly Zero-energy Buildings apply from the end of 2018. According to Transparency Market Research, 2015 the global annual installation of BIPV systems goes from 343.1 MWp in 2012 to 1,152.3 MWp in 2019 with a CAGR of 18.7 %. NanoMarkets, 2015 predict the BIPV market will grow from € 2.6 billion in 2015 to 7.9 billion in 2019.

Completion of the project, mean the PV Roofing System will reach the price level of conventional roofing materials. The *global roofing market* was valued at € 56.58 Billion in 2013 and is anticipated to reach € 85.62 billion in 2020, expanding at a CAGR of 6.3% between 2014 and 2020. In terms of volume, the market stood at 10,600 million square meters in 2013 approximately 70 million roofs of 150 m2. The market is high volume and very attractive for PV Roofing System. Making PV Roofing System competitive to conventional roofing materials will raise the market volume with 8-10 times compared to the BIPV market.

The thermal absorber still needs further research and development, which mean it is not in the commercialisation stage. Therefor the business plan has not been updated for that area, but the strategy still includes that part, due the positive results of the simulation. New material or supplier could solve the problem at the stress test of the thermal absorbers. Innogie will continue to develop the thermal absorber to fulfil the strategy of offering add-ons for the PV Roofing System. From the good experience of going into the commercialisation stage with the PV part, Innogie is eager to do the same with the thermal absorbers when they are ready.

1.7 Project conclusion and perspective

The conclusion on the project is the PV part has been very successful with two prestigious design awards which gave the golden opportunity to reach to the commercialisation stage and market launched the product. The PV Roofing System has been patented to secure the IPR and a new business plan has made.

When pressure was added to the system, the material became unstable and eventually punctured. Therefore further test on the material and close cooperation with the existing supplier could solve the problems. Other suppliers could be tested as well, before new research and development of the thermal absorbers should begin. The supplier is currently doing internal testing of the material types.