(Projects submitting final reports after 1 January 2014 must use this format.)

LIFE Project Number

LIFE09 ENV/SE/00035

FINAL Report

Covering the project activities from 01/09/2010 to 31/03/2015

Reporting Date

26/06/2015

LIFE+ Dyemond Solar

Project Data

Project location	Stockholm
Project start date:	01/09/2010
Project end date:	31/12/2013 Extension date: 31/03/2015
Total Project duration (in months)	55 months (including Extension of 15 months)
Total budget	€ 3 522 312
Total eligible budget	€ 3 484 567
EU contribution:	€ 1 735 846
(%) of total costs	49,28%
(%) of eligible costs	49,82%

Beneficiary Data

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2. Executive Summary

The potentially usable radiation of the sun is about 1.9×10^8 TWh per year which translates to approximately 170 times the total amount of energy of global coal reserves. This means the solar energy reaching the earth's surface during only 6 hours is enough to meet all global energy needs on an annual basis.[1]

The Dyemond Solar project has proved the production potential and scalability of screen printing as a production method for manufacturing dye sensitized solar cells.

This solar technology in combination with the chosen production method is sustainable and environmentally friendly with no toxic emissions, allowing for a pilot plant to be situated in the city centre of Stockholm.

Introduction: The aim of the project was to demonstrate the production of flexible, transparent dye-sensitized solar cells. Other goals of the project included efficiency, life-time and bill-of-materials. In November 2014 Exeger produced dye-sensitized solar cells (DSCs) in the pilot production plant built and developed at the premises in central Stockholm. In order to make these DSCs commercially relevant a number of criteria had to be fulfilled.

DSCs are ideally suited for a variety of real life conditions thanks to their inherent characteristics. They are based on the principle of photosynthesis allowing for light to be captured in a variety of sub-optimal lighting conditions. This means they are less sensitive to light angle and higher temperatures than previous generation solar technologies. They also excel at low light conditions which means fog, smog, cloudy weather have little effect on efficiency. They do not contain toxic or scarce materials and are more cost-efficient to manufacture. The Exeger proprietary DSC adds additional benefits with design possibilities allowing for seamless integration into a wider range of products, without negatively affecting form or function.

Administration: For a project to succeed over the span of four years it is of utmost importance to have a solid plan with well-defined milestones. Once a project is properly planned, flexibility and adaptability are crucial because a plan can never be followed to the point throughout a project's lifespan. In that spirit, the project management has led the work throughout the past four years with clear and realistic milestones. This has been an absolute must when developing a new technology into demonstration of production. The company has grown during the project from an 8 employee company to over 30 employees by the end of the project. While this growth has been necessary for clear reasons, it has posed challenges for the project management in transfer of information and structural efficiency. Once again, this reflects the importance of having a plan which you can adapt to necessary unforeseen events while always focusing on the common goals.

Technology: The development from a lab-scale setup to a pilot line demonstrating a $50m^2$ daily capacity was a learning experience on all fronts. The solar technology produced at the pilot line is itself unique. The pilot line and the production method chosen is also unique for the production of DSCs. Combining a new solar technology into the development of a new pilot plant with a unique setup and machines was very ambitious. Scaling up from lab-scale required designing custom-made machines for every process step. Once the machines where designed and built, they needed to be individually tested to ensure they met the necessary standards. Once the tests where successfully completed, the integration of the different machines began in order for the pilot plant to work as a unit. After four years of scaling up, designing, testing, manufacturing, installing, more testing, integration and quality control, the demonstration in November 2014 was the final technical milestone of the project and was achieved successfully.

Dissemination: Since the demonstration of a pilot plant has the potential to start a whole new field within the solar industry, dissemination is an extremely important part of the project and for the success of the spread of the technology. Solar energy is a global market and with that comes certain prerequisites. The dissemination activities have mainly been focused on the EU but have been directed to a global community to fully spark European interest. The reason for this being that some of the world's largest events are in the Middle East and Asia which attract academia, government, industry and the general public out of Europe and to these events.

Throughout the project, dissemination work has also been done at the premises. To demonstrate a working pilot line has been pivotal for the success of the dissemination strategy. Seminars, academic visits, government visits have been arranged as well as visits from industry leaders. Each event has always been met with strong positive reactions to the project and the future global potential of the technology and production scalability.

3. Introduction

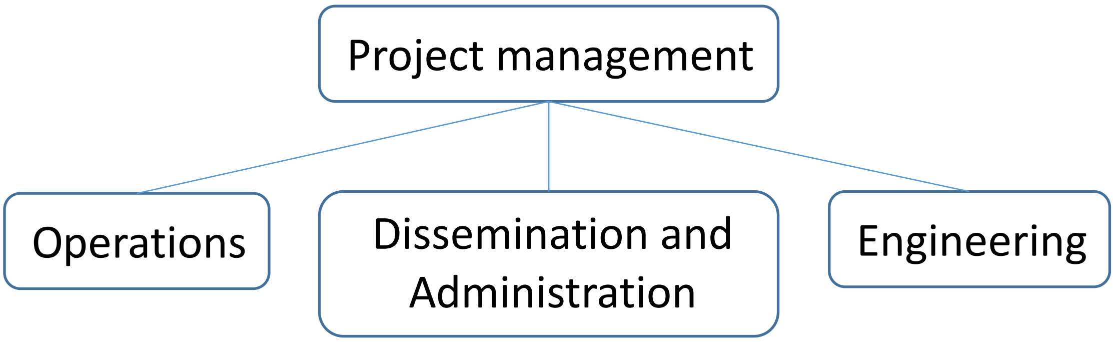
The DYEMOND SOLAR project comprises a decisive and crucial contribution to implement the environmental objectives set out by the EC in order to stop or slow down global warming. The project supports the policy area “LIFE+ Environmental Policy and Governance” and its sub-area 1. “Climate change”. In addition, it supports sub-area 11 “Innovation” by assisting in the implementation of the Environmental Technologies Action Plan (ETAP). Contributing to stabilising greenhouse gas concentration at a level that prevents global warming above 2 degree C the project is also in line with national annual priorities for Sweden as well as Swedish environmental objectives that include “Reduced climate change”.

Exeger planned to develop and demonstrate production of a new solar cell technology with the hypothesis that it could be produced cheaper and more efficiently than other competing technologies. The hypothesis was verified in November 2014 with the successful demonstration of the pilot plant capacity.

Developing a screen printing based production method for large scale manufacturing enabled wider capabilities in design, flexibility and customization.

The project results include lower production costs, increased energy efficiency, lower emissions and more environmentally friendly end products. This will open up new markets for both production and usage of products. The lower production costs specifically enable wider distribution and increased energy efficiencies will spread the sales ensuring global reach and resulting in lower greenhouse gas emissions, slowing global warming.

4. Administrative part



Coordination of the project has been done through regular meetings, scheduled for the different project teams. Machine construction meetings have been held in some periods of time as often as daily. During the most intense demonstration phase these meetings were of the stand-up type taking place in the production hall several times each day. The subsequent demonstration for external visitors and such during the months following November 2014 was held at a slower pace, requiring less of immediate coordination and more focus on the overall coordination. The coordination of the project as a whole, with all the components such as personnel, material, machines took place through management meetings every fortnight to ensure for instance enough material and personnel in the right place, at the right time.

The amended project outline and timelines is found below.

– Tasks		2010	2011		2012		2013		2014		2015
		Sept-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June
Overall project schedule			P			P	P	P			P
Action 1	Proposed										
	Actual										
Action 2	Proposed										
	Actual										
Action 3	Proposed										
	Actual										
Action 4	Proposed										
	Actual										
Action 5	Proposed										
	Actual										
Action 6	Proposed										
	Actual										
Action 7	Proposed										
	Actual										

End date: 2015-03-31

P=Progress reports

Proposed refers to the amended application, 15 additional months granted Aug 2013

The changes in comparison with the initial time plan was that the Action 2 was extended with 15 months, affecting the other Actions also with 15 months.

4.2 Evaluation of the management system

The project management system has developed over time. Given the growth of the company with new people with different skill sets being employed, we have continued to develop the management process. The steering group that was crucial in the early years successively adjusted their input once more personnel was employed that could take over some of the management processes.

Communication with the Commission and Monitoring team: In June 2013 we sent in an amendment to the Commission asking for an extension of the project with 15 months and this was granted in August 2013, the new end date being March 31 2015. The Commission has visited us to see the progress several times during the project; March 2011 (Mission report), April 2012 (Monitoring report), March 2013 (follow up of the mid-term report), February 2014 (Mission report) and December 2014 (preparation for Final report due June 2015).

Reports on progress have been sent in regularly (see list below) and the feedback from the Commission has been fast and clear. After the granted extension in August 2013 we have communicated our progress in 7 reports.

2011-05-01: Inception report, including Deliverable 1.1, 1.2 and 1.3
2012-12-27: Mid-term Report, including Deliverable 2.1 (first part) and 4.1
2013-06-27: Progress Report
2013-12-31: Progress Report
2014-09-30: Deliverable 3.1 and 3.2
2014-10-02: Deliverable 2.2 and 2.3
2014-11-04: Deliverable 4.2
2014-11-30: Deliverable 3.3 and 4.3
2014-12-04: Deliverable 5.1, 5.2 and 5.3
2015-02-27: Deliverable 2.1 (final part)

Summary of the Dyemond Solar project September 2010 – March 2015

Milestone	Tasks	Actions	Deliverables	Time span	Status	Report
M1 Completed planning of project	1. Project management and planning	To perform all necessary project management activities during the project for quick and efficient decision making and optimum harmonization of actions	1.1. Detailed plan for actions 2-5 including technical specifications and preparations	Sep 2010 - Dec 2014	COMPLETED	2011-03-15
			1.2. Technical description of pilot line production process		COMPLETED	2011-03-15
			1.3. Reporting docs for the evaluation phase		COMPLETED	2011-03-15
M2 Completed assembly of Pilot Plant	2. Installation of pilot production line	To execute the assembly and installation of the defined pilot production system as planned in action 1	2.1. Report from all parts assembled individually and tested	Jan 2011 - June 2014	COMPLETED	2012-12-27 (first part) and 2015-02-27
			2.2. Installation report of installed pilot line		COMPLETED	2014-10-02
			2.3. Technical description of installed pilot line working as a unit according to specifications		COMPLETED	2014-10-02
M3 Completed demonstration of prototype	3. Demonstration of pilot production line	To execute a complete demonstration of the installed and tested pilot production system as assembled in action 2	3.1. Report of measurement data that starts to feed back into the pilot line to improve performance	Jan 2012 - Dec 2014. Demonstration of production prolonged to Mar 2015, not affecting the Final Report or overall conclusions	COMPLETED	2014-09-30
			3.2. Production of DSC with 1DPC		COMPLETED	2014-09-30
			3.3. Report of technical specification and performance of demonstrated pilot plant		COMPLETED	2014-11-30
M4 Completed monitoring of the different parts	4. Monitoring of Project and Demonstrations	To monitor pilot production and demonstration and the overall project with the aim to ensure efficient and successful demonstration of the innovative production technology	4.1. Report from installation of monitoring systems	Jan 2011 - Dec 2014	COMPLETED	2012-12-27
			4.2. Quaterly monitoring data report		COMPLETED	2014-11-04
			4.3. Detailed monitoring report		COMPLETED	2014-11-30
M5 Evaluation of devices, equipment and people completed	5. Evaluation of EXEGER Technology	Thorough evaluation of Exeger technology to secure full scale implementation of the technology in Europe	5.1. Evaluation report of equipment and methods	Oct 2011 - Dec 2014	COMPLETED	2014-12-04
			5.2. Documentation and information from visitors/agencies		COMPLETED	2014-12-04
			5.3. Evaluation report of pilot plant and installation		COMPLETED	2014-12-04
M6 Dissemination to target groups and others completed		Dissemination of Project Results	6.1. Website up and running	Jan 2011 - Mar 2015	COMPLETED	Website operational 2011-03-22
			6.2. Articles in trade periodicals		COMPLETED	
			6.3. Guided visitors/tours at demonstration site		COMPLETED	
			6.4. After-LIFE communication plan		March 2015	
M7 Project management completed		To perform all necessary project management activities during the project for quick and efficient decision making and optimum harmonization of actions		Mar 2015	COMPLETED	

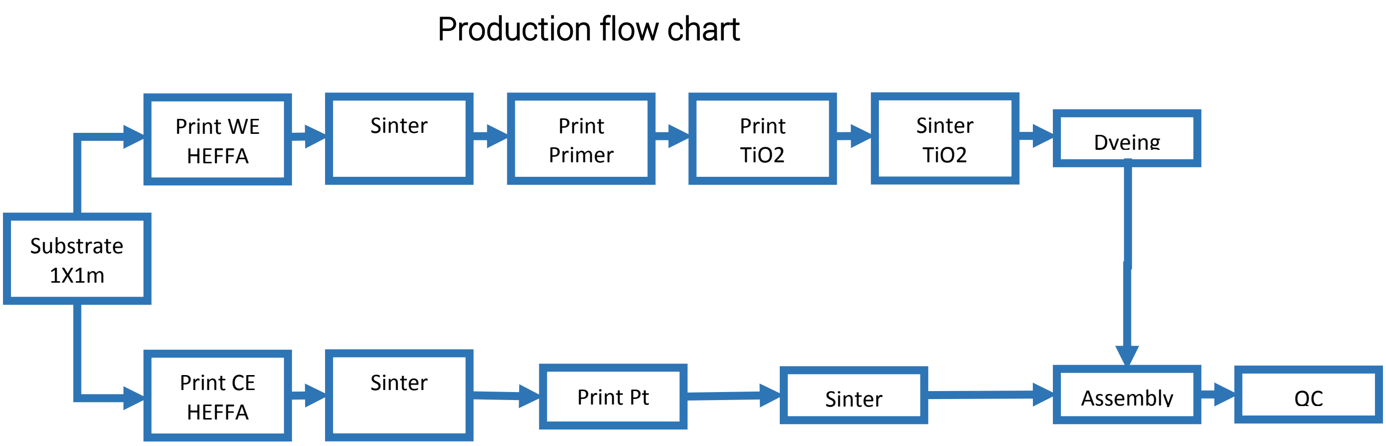
5. Technical part

In the coming pages the technical progress will be described, per task.

Task 2: Installation of pilot production line

For thorough description of the development and installation of the pilot production line, see the Reports for Deliverables 2.1, 2.2 and 2.3.

Below is an illustration of the chosen processes for demonstrating production of dye-sensitized solar cells at EXEGER's facilities.



The production flow chart depicted is a sequence of individual process steps in the production flow. The resulting pilot line is capable of producing 200 pieces 0.5m x 0.5m modules per day which corresponds to 50m² solar cells per day.

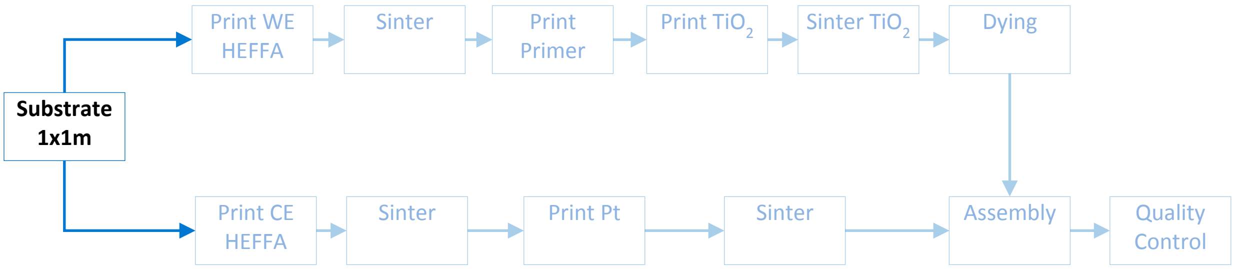
Preparations of the facility

In order to install the pilot production line several things excluding the machines needed to be in place. This work started with the finalization of the layout planning of the pilot plant:

- Where should the machines be placed
- What hypermedia such as water, compressed air and electricity must be in place
- Which walls needed to be removed
- What new walls needed to be built etc.

Dr Lena Apelskog Killander, and later Anders Landström, was responsible for the specific steps mentioned above. During the development of the company and the processes some of the chosen solutions had to be altered, especially the change of supplier of the printing lines led to new requirements (see Inception Report 2011-05-01). When finalized the pilot plant ran efficiently with respect to use of hypermedia, avoiding unnecessary lighting or water usage. Focus from start was put on making this an environmentally sustainable factory, in line with the guidelines for LIFE+ projects. All processes were developed in the laboratory before the production machines were constructed, ordered and in place. The assumption was that what worked in the laboratory should work in large scale as well. These smaller scale processes and material development also required hypermedia installations, in principle the whole laboratory had to be re-built to accommodate the right water, air and electricity.

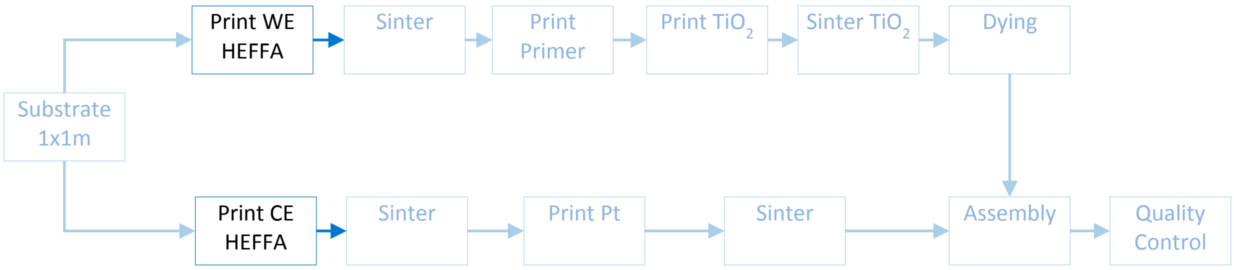
The machines and processes



The first step in the production of EXEGER proprietary variant of dye-sensitized solar cells (DSCs) is the production of substrate. The first machine constructed for this purpose produced 0.25 m^2 sized substrates and the capacity was approximately one tenth the requirement for fulfillment of Dyemond Solar.

In order to produce the size and amounts of the substrate required for delivery in the Dyemond Solar project we first made a prototype machine where the capacity was demonstrated, spring 2013. This prototype machine was manual and used for testing the concept and the processes. With the learnings from this full-scale prototype machine we constructed a more automatic machine, with larger capacity which was in full production in the summer of 2014.

The construction team for this more automatic substrate machine was a large assembly from different functions of the company, in order to capture both process and machine knowledge. The team was headed by Head of Formulation, Dr. Martin Möller, and the co-workers most involved in this project were senior mechanical engineer Kjell Blank who did the PLC programming, Lars Netzler who constructed, ordered and built different parts of the machine and Anders Landström who ensured water and electricity supply. Most of the development work on the substrate has been performed outside the Dyemond Solar project. Results from this development could however subsequently be used for improvements regarding the architecture of the solar cell, this was important regarding satisfaction for the future customers, ensuring interest in the technology and spread of it.

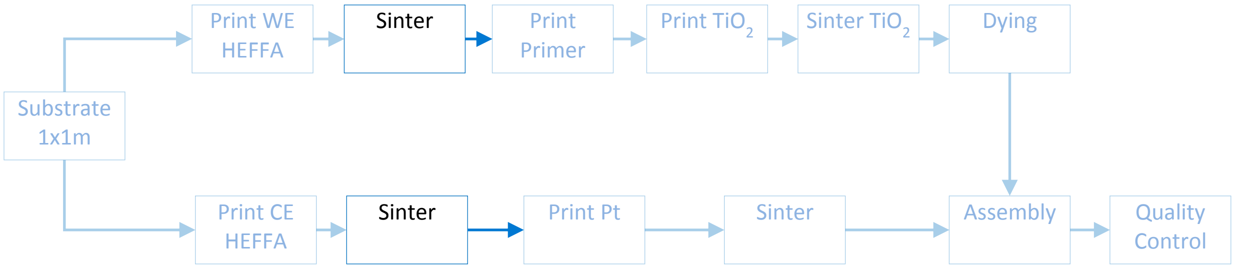


The next step in the production process is the printing of working electrode (WE) and counter electrode (CE) HEFFA conducting substrate and for this we installed the production-scale printing and drying lines. Our printing line manufacturer was chosen because of their capacity and for being a well-known supplier in this field, thus capable of making the custom adjustments needed for our specific production. The initially chosen supplier had mislead us regarding capacity and service, this delayed us by over a year, and led to EXEGER asking for an extension of the Dyemond Solar project by 15 months. The 15 month extension granted from the Commission allowed us to find the new supplier for the printing line and in hindsight it would have been detrimental for the project to stay with the original supplier. It is our conclusion that the project would not have been successful without the additional time needed to find the new supplier.

The printing and drying lines consists of:

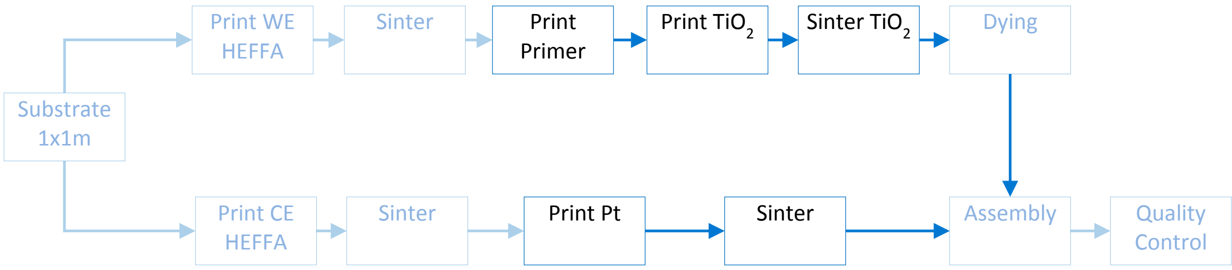
- Destacker (unloading the substrates from a cassette piece by piece and for automatic feeding)
- Automatic alignment of substrates (sections for rough and fine alignment, 10 µm accuracy)
- Screen printer (including automatic alignment to 10 µm accuracy)
- Dryer consisting of 4 sections (2 sections hot air and 2 sections hot air and infrared)
- Unit to turn substrates 180 degrees
- Automatic alignment of substrates and stacker (into cassette)

All these parts, the handling, printing and drying, were tested in the factory in Germany December 2013 (Factory Acceptance Test, FAT), then again at EXEGER premises January 2014 (Site Acceptance Test, SAT). The capacity of these custom-made printing and drying lines exceeds the goals of the Dyemond Solar project. We have therefore only reported costs matching the capacity required for this project; see more in the Financial part of this Final Report.



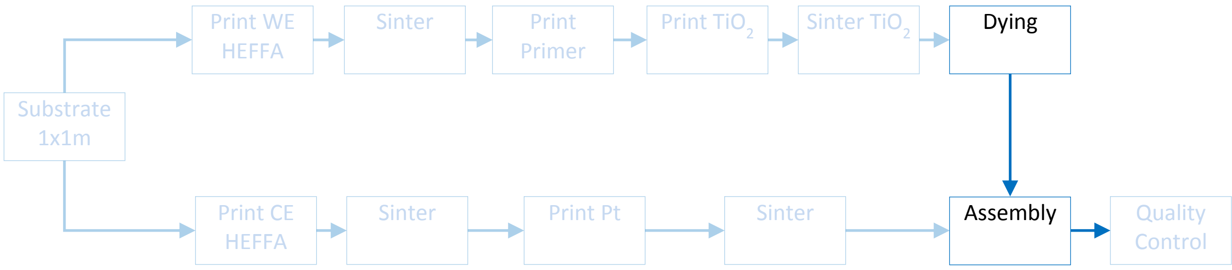
Sintering the material, the process step following printing WE and CE HEFFA, is done in a custom-made oven. This oven was installed on site already November 2012 and has since been further developed and optimized. A new interface for controlling the oven, both remotely and in-house was constructed out of necessity after delivery. This required PLC programming and new equipment for controlling the power supply. Another added construction was the cooling system, necessary for optimizing the oven use and capacity. Different cooling systems were constructed and tested by senior mechanical engineer Kjell Blank. The chosen cooling system was fully functioning in summer of 2014.

Custom-made sintering oven.



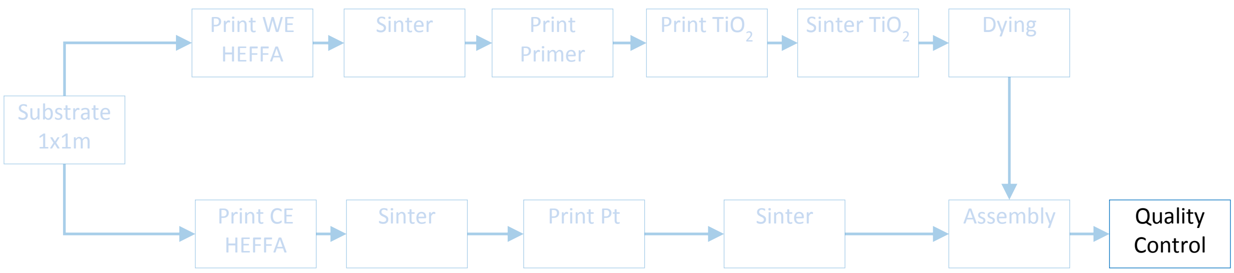
The process steps following this oven step are more printing steps, again in the production-scale printing lines, followed by a new sintering procedure, in a custom made furnace from Nabertherm. Due to delay from the manufacturer and despite our intense communication with them in order to understand what could be done to speed up the process, the Nabertherm sintering furnace arrived a month later than communicated at the time of order. In September 2014 we were able to perform the SAT (Site-Acceptance Test). This forced us to test the procedures more thoroughly in the smaller scale during the summer of 2014, in a very similar oven from Nabertherm but with smaller dimensions. These tests where translatable into the larger oven, even if the exact protocols still needed some development, which was handled by Blake Wolf, researcher and Kjell Blank, senior mechanical engineer. The full production line including the Nabertherm sintering furnace was run only some weeks before the demonstration run.

Installation of the furnace was very efficient, involving Blake Wolf and Anders Landström, in addition to the personnel from Nabertherm. The protocols that were worked out showed the capacity of the furnace to be more than 100m^2 of material in each run so the capacity greatly exceeds the requirements in the Dyemond Solar project and the costs have thus not been attributed to the Dyemond Solar project.



WE substrates are dyed in a custom made dyeing machine, proprietary construction of EXEGER while CE substrates are printed once more in the production-scale printing lines. The dyeing machine, an in-house construction, demonstrated the ability to, in a new way, dye large amounts of material. Dyeing is the most crucial step in the production of a DSC as the dye is where conversion of photons takes place and therefore current is generated. The responsible scientist Dr. David Bevk worked very closely with the machine construction team headed by Stefan Olin to solve the upcoming issues regarding for instance drying times and storage.

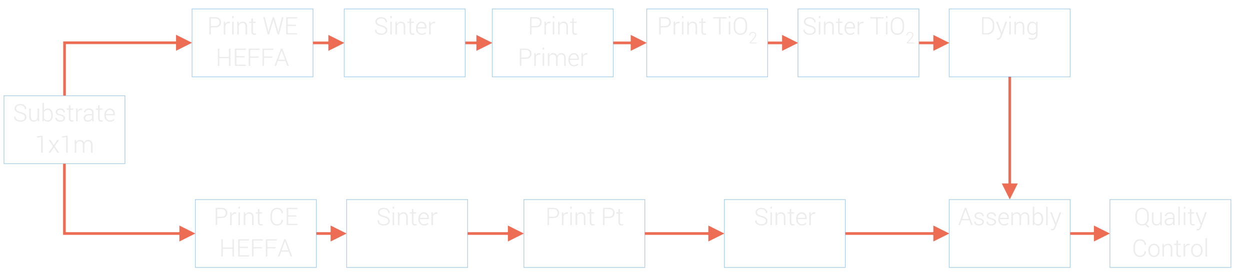
The dried electrodes were then assembled together in assembly machines constructed and built on the EXEGER premises. Immediately prior to aligning the solar cell components in the assembly machine, electrolyte is deposited onto the electrodes. During the demonstration week we had a custom made semi-automatic machine, constructed and built in-house by mechatronics engineer Christian Aguayo. The initial testing rounds of the assembly machine focused on the heating steps to ensure the capability of the machine to run the required cycles. Efforts had to be put into the optimization for removing defects. The testing was led by Dr. Sara Green in close contact with the machine constructors and employees doing the assembly, Jagica Kelava and Sahar Sultan.



The produced solar cells were then controlled using our custom made QC (quality control) equipment. Dr. Jarl Nissfolk constructed an LED-box which was put together by mechanical technician Tomas Wahlund. This prototype version was further developed into a larger version for the demonstration week, based on the learnings from the use of the prototype. This time embedded engineer Kartik Karuna was pivotal in putting the whole thing together.

The equipment consists of a 64-channel IV measurement equipment which was constructed, built and installed during fall 2014. This equipment and processes around it included:

- Completed quality control analysis software for the pilot line.
- A device code system for traceability of the device production history.
- A large area solar simulator, integrated in our quality control software.
- Implemented standard operating procedures for improved reproducibility and yield.



Before running the pilot line as a unit according to specifications, the different parts from corresponding processes needed to be tested together and logistics and transfer between different machines sorted. In some cases this was very straightforward, in other we realized that the storage of partly processed material needed to be solved. The substrates produced were transferred to the production-scale printing lines for the first step of printing. Different modes of transportation were tested, the substrates are light-weight but 1m x 1m is bulky and requires an effective transfer system. After having tested several different carrying plates we opted for the simplest and most cost-effective choice made of cardboard. Since the material is thin and light-weight storage per se was not difficult but it still required a well-developed monitoring system, described under Task 4.

From storage the substrate was transported to the production-scale printing line where the first layer was deposited. At the end of the printing line the material was again stored before being transported to the first sintering step. We verified that the material could be stored, both before and after sintering, both outside and inside the oven without any effect on results in the following steps. The next printing steps were carried out in a similar manner, and the resulting material was stored and then sintered.

The specification of the line was to be able to deliver $50m^2$ per day during a demonstration period of 5 subsequent days with a certain efficiency, lifetime, bill-of-material and appearance. The design regarding transparency was chosen after workshops with potential customers, and below is a picture of the EXEGER CTO of Dr. Henrik Lindström holding a 0.5m x 0.5m ($0.25m^2$) flexible, transparent, light-weight (the weight of the solar cell below is approximately 200 grams) EXEGER dye-sensitized solar cell.

Parts of the demonstration focusing on each process step was integrated with the installation of the pilot production line, the next step was running the line for one week demonstrating the overall capacity.

Task 3: Demonstration of pilot production line

Details are found in Reports on Deliverables 3.1, 3.2 and 3.3.

Substrate: As part of our developmental work we evaluated different types of material as substrate, including FTO-coated glass and proprietary variants of substrates, in the pilot line. When we started to get measurement data from the pilot production from the different materials we concluded that our proprietary material developed outside Dyemond Solar was to prefer as substrate. The glass is more expensive and less environmentally friendly due to weight (which translates to higher CO_2 emission when transported) and production process (heavier materials in the printing line require more energy to produce). In the production glass requires extensive handling such as cutting in special equipment. The substrate production was then optimized for yield and quality. The yield was dependent on several different parameters:

- Machine performance and up-time
- Input material properties
- Personnel training level & handling (more details in the Reports for Deliverable 3.3 and 4.3).

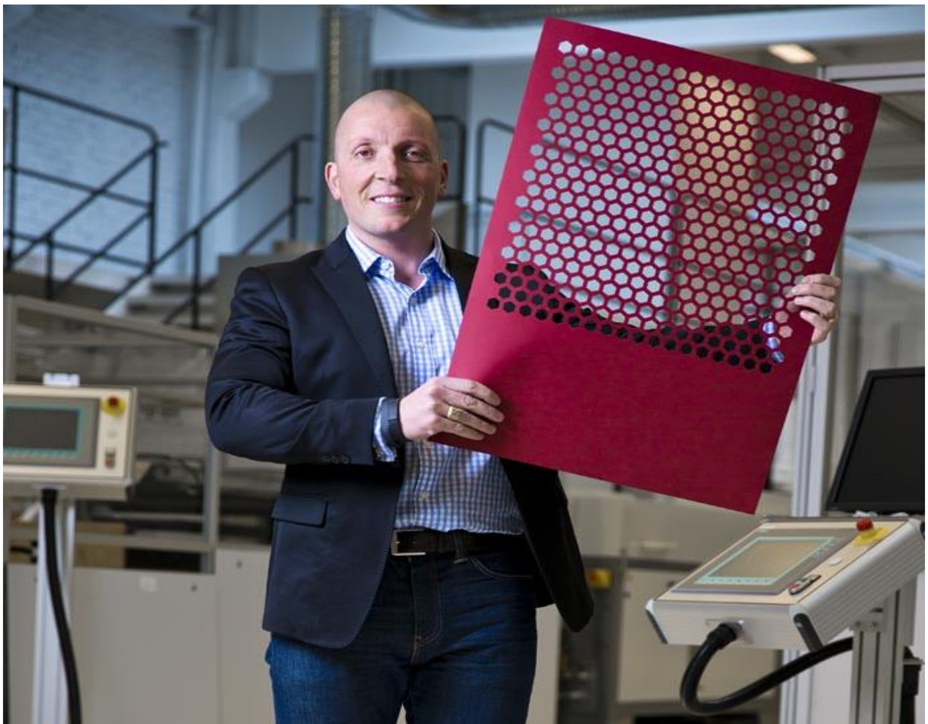
Quality was assessed continuously during the production and every substrate was inspected before it was used further down the production line. The inspection protocols focused on the requirements for the subsequent steps, the need for the substrate to be planar and free of defects.

Printing different inks on different substrates and quality control of these prints requires equipment that in large enough scale can produce the different ink and our beadmill has been pivotal in this work. The quality control of the printing took place as outlined in the annex regarding monitoring, evaluating the resolution and the thickness, as well as the reproducibility.

Sintering processes were developed and different protocols tested, the data on thickness and sheet resistance continuously guide us in the work, as well as the data from the overall performance of the solar cells.

Different prototypes have been designed and produced, some examples are shown below, where we printed the LIFE logo to show the versatility using screen printing technique (the dye is red) and also introduced our transparency concept with a honeycomb pattern, chosen in close collaboration with our future customers, to be used for simultaneous shading and electricity production, in for instance skylights.

Example of how a screen print can look, the same pattern will be present in the resulting solar cell.



Another example of a pattern requested by one of EXEGER's potential customers, demonstrated by EXEGER CEO Giovanni Fili.

In order to show the pilot line functioning as a unit we needed to transfer and track material through all the steps in a reproducible way. The monitoring reports, Deliverable 4.2 and 4.3 describe the results from this in a very detailed manner. The persons responsible for the overall resourcing and material being present at the right time, at the right place, during the fall of 2014 were Drs Jarl Nissfolk and Camilla Niva. A balanced production at every step is key for a continuous flow and it was absolutely necessary not to over or under-produce at any point. Three teams were formed:

1. Substrate production
2. Printing & sintering
3. Assembly.

Almost all employees were working with Dyemond Solar and the demonstration during the final months of 2014. To balance the efforts some personnel could work in more than one team, also allowing knowledge transfer. This knowledge transfer proved very important, it ensured the personnel focusing on making the most important adjustments.

To measure the performance in various steps we monitored the area of produced material vs the usable area of the material. This gave us both the overall amounts as well as the yield and we learned which part of the process to focus on to improve the overall yield. As discussed in Deliverable reports 3.3 and 4.3 we realized that the biggest losses occurred in the Nabertherm sintering furnace. This oven had not been in place at EXEGER for more than a couple of weeks and this could explain the results and we needed to continue running the pilot line for demonstration and further learning purposes during the first quarter of 2015. These further developments were done at a much slower pace, in order for the visitors to be able to see all the steps and also to focus on further increasing the quality in each step.

The solar cells produced are thin and light-weight and hence storage is no problem. 1 month of production at 200 units daily weighs 80 kg and takes up about 1m^3 of shelf storage. Samples used for ensuring life span and power density were taken randomly, as well as for the cells with the highest power density.

The demonstration period of 5 consecutive days took place during the last week of November 2014, in accordance with the revised time schedule agreed with the Commission August 2013. Ramping up of the production of different components in the full production line had been ongoing for some weeks. During the demonstration week the assembly goal of $50m^2$/day of transparent, flexible solar cells was successfully achieved. $50m^2$/day production of these specific solar cells translates to 200 pieces daily. The cost of material was within the bill-of-material of 80€/m^2, with large-scale quotes acquired. Accelerated life-time tests according to industry standards showed less than 10% loss of electrolyte, demonstrating a sustainable product. In addition, long-term testing of solar cells driving a mechanical device has shown that cells made in November continue to deliver power March 2015, as expected.

The demonstration of production continues into 2015, as well as further into the future. EXEGER aims to spread this novel technology, demonstrating cost-effective production of dye-sensitized solar cells, with the potential to reach numerous energy demanding markets. These light-weight, flexible solar cells can be used in many possible applications. Increasing the number of applications also increases the potential impact this technology can have on the environment and the ratio of energy coming from renewable sources. The patterns chosen for this project have drawn attention from users such as Fasadglas (largest façade company in the Nordic countries) who clearly see the added potential in providing façade elements with integrated solar cells.

Task 4: Monitoring of Project and Demonstrations

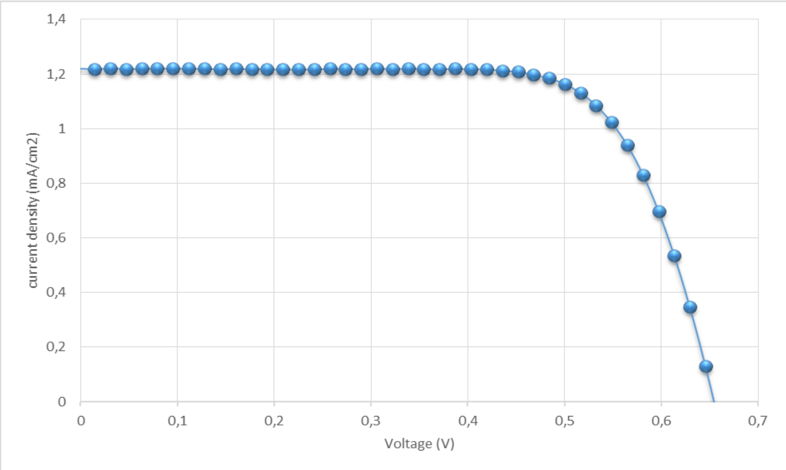
Monitoring has been done regularly throughout the project, to ensure the produced material has the quality required and also that the processes are cost-effective and sustainable.
The details can be found in Reports on Deliverables 4.1, 4.2 and 4.3.

In brief, the solar cells before assembly are sensitive to temperature and humidity so as a first step we installed equipment to log these parameters. The logging initially took place in the lab and then upon installation of equipment in the production hall. When the logging systems for outer parameters where installed we focused on the control of material. The monitoring systems installed regarding the control of machinery and equipment procurement and reporting templates, this was reported to the Monitoring team with the Inception report from March 2011.
The next step was then to construct the solar cell measurement equipment and to program the software controlling it. This was custom-made by Dr Jarl Nissfolk and this work was started early 2012.
Once the production machines were installed in the production hall we could start using the prepared monitoring documents for substrate, inks, sintering and such. Once the pilot line was functioning as a unit, we developed monitoring documents for the production of each batch of solar cells.
Depending on the process, the batches are of different sizes. Some of the processes can handle substantially larger sizes and this can be used for speeding up the overall process. For this to work, the system for tracking material in different phases of the production must be very well-developed. EXEGER has implemented a batch sheet system where every new batch is given a unique number which can be tracked backwards. Each solar cell finally gets a number based on the name given from assembly batch sheet.

The monitoring documents for controlling the quality and for keeping track of different processed material were attached as annexes to the Report on Deliverable 5, an example is found below:

Thieme Printline 1 Batch sheet					PL1#3
version 2014-10-29					
Number of sheets processed in the batch			Date		
Number of scrapped sheets during process					
INCOMING BATCH			Operators		
Thieme printline 1 [PL1]	Thieme printline 2 [PL2]		signature		
LVS Vacuum oven [VO]	Paper machine [PM]				
Batch numbers					
INK batch ID		Pt			
Heffa	TiO2	Block			
Time start		Time end		Screen ID	
Temp start		Temp end		mesh type	
Humidity start		Humidity end			
Velocities	Print velocity		Functions	Multiple prints	
	Flood velocity			Print ink recovery	
	Filler pressure			mm Ink recovery start	
print Beam	mm Print start			mm Ink recovery end	
	mm Print end			Anti-Drop Flood bar	
	mm Elevation			Anti-Drop Squegee	
	squegee pressure		Gripper	mm "Seize Product"	
	mm off contact			mm "Hitch gripper"	
Times	Squegee inversion			Retract gripper	
	s bar inversion			mm "return Gripper"	
	s dwell down			mm "Opening Position"	
Transport	conveyer velocity			mm/s Gripper velocity	
	% Vacuum			gripper axis to open	
	% blow air		Squegee bar	Squegee angle	
Dryer	Temp [C]		Infra Red %		Fan [%]
	Temp [C]				Fan [%]
	Temp [C]				Fan [%]
	Temp [C]		Infra Red %		Fan [%]
	Conveyer Speed [m/min]				
Quality control, print nr	Seepage	Fall on belt	transport	Notes	stacking
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

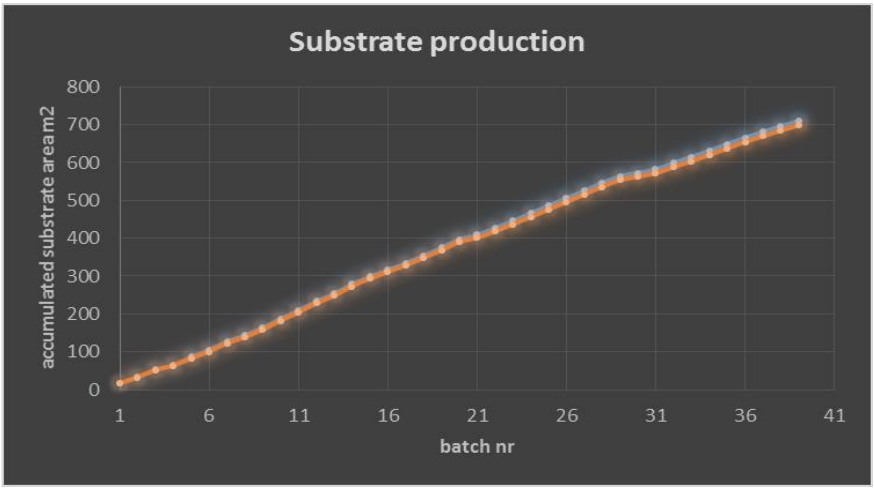
Each individual solar cell is measured for power density after its assembly. The measurement takes place in the aforementioned custom made LED-box, with the previously developed settings. The result is four important values: efficiency, fill factor (FF), current and voltage.



Jsc: 1.2mA/cm², Voc: 0.65V, FF:73.2%, efficiency: 5.8%, measured area: 7.5cm².

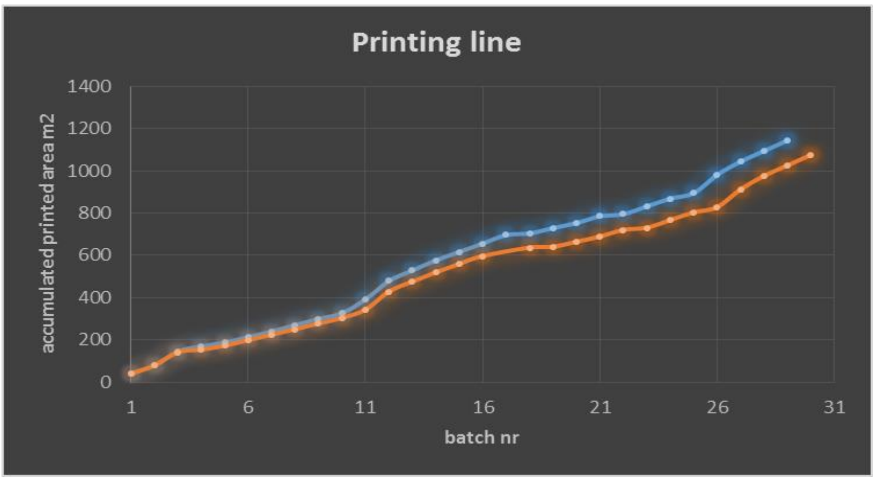
In addition to these objective measures, each solar cell was also inspected for visual impression. Dye-sensitized solar cells for integration into buildings (BIPV) must in addition to sufficient efficiency also fulfil requirements regarding aesthetics which is clear after numerous workshops with potential industrial partners.

In order to monitor the production on a larger scale we have generated data on produced material vs usable material. In the graph below we have 2 lines showing this, in blue the produced amount of material, accumulated versus batch number of, in this case substrate, and in orange the usable area. The lines overlap indicating a high yield, almost all substrate is taken further into production. The data found below is an example from part of the demonstration, the rest is found in Deliverables 4.3.



The total accumulated produced and usable substrate area versus batch number. The blue and the orange line depict the produced and the useable substrate area, respectively.

The next example is from another process, printing of substrate. The blue and orange lines depict produced and usable area respectively.



The total accumulated produced and usable printed substrate area versus batch number. The blue and the orange line depicts the produced and the useable printed substrate area, respectively.

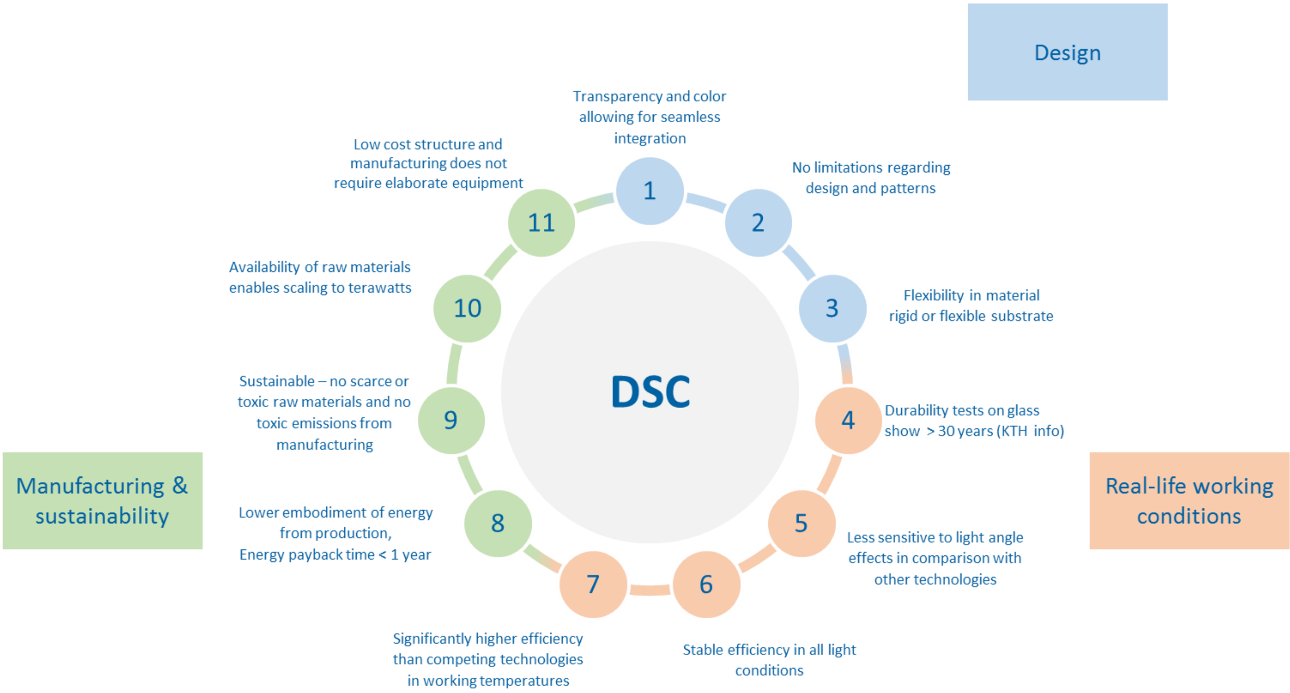
During the continued demonstration in the first quarter of 2015 we focussed on further increasing the quality of the processes with the aim of the blue and orange curves to overlap. New protocols for printing and also for sintering (the two processes with the lowest yield, but still above 90%) made us come further towards the goals.

Task 5: Evaluation of EXEGER Technology

Evaluation of the EXEGER developed technology was an integrated part of the project. In order for the technology to be sustainable and to have a chance of being a game-changer it was an absolute must to continuously verify the needs and possibilities of the market and customers. The technology has been evaluated both from a market and customer perspective, as well as from a production and environmental perspective.

Solar energy is free and in abundance. With light surrounding us all day it is natural to see the potential in the ability to convert all light, to energy, not only sunlight. Below is a comparison of commercially available solar technologies, spanning from 1st generation silicon solar cells to cutting edge next generation DSC, namely EXEGER's solar technology. As can be seen the solar cells made by EXEGER span the most possibilities of the solar cells technologies present to date.

		DESIGN				PERFORMANCE			
		Colour/ transparency	Pattern	Flexible	Large homogenous surfaces	Indoor power density	Outdoor module efficiency	Sensitivity to light-angle	Module price per Watt
1st generation PV	Mono-crystalline	No / No	No	No	No	No	20.5%	High	0.72 $/W
	Multi-crystalline	No / No	No	No	No	No	18.6%	High	0.66 $/W
2nd generation PV	Cadmium telluride	No / No	No	Yes	No	No	17.0%	Medium	0.58 $/W
	CIGS	No / No	No	Yes	No	No	16.6%	Medium	0.58 $/W
	Amorphous silicon	No / Yes	No	Yes	No	Low	5.0-8.0%	Medium	0.49 $/W
3rd generation PV	DSC	Yes / Yes	Yes	Yes	No	Medium	10.3%	Low	N.A
	EXEGER	Yes / Yes	Yes	Yes	Yes	High	Not disclosed	Low	Not



Above is a picture outlining the advantages of standard DSC technology in comparison to other solar cell technologies. In addition to the above advantages, EXEGER also boasts superior capabilities including:

- Pattern
- Homogenous surfaces
- Light-weight

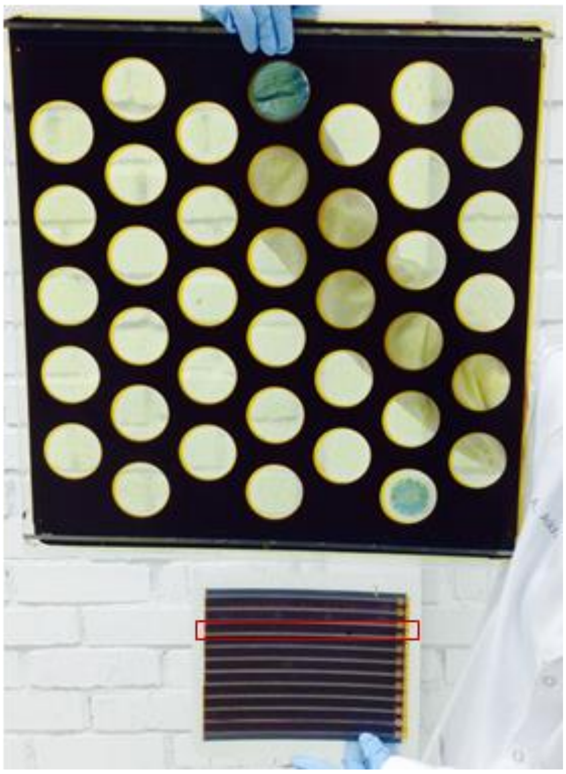
This underlines the exceptional position of EXEGER in the photovoltaic field. With the support of the EU Life+ Project, EXEGER is the only company that can demonstrate industrial scale production which can be spread globally thanks to its modular design. This can lead to a break-through for the large scale production of DSC.

EXEGER has always worked closely with different industrial actors to ascertain that the potential products are of industrial relevance for the market and the end-customers. These include façade companies, architect firms, and other. The requests for visits to the production facility built in central Stockholm have revealed the ever growing interest for this technology. EXEGER has always taken the chance to describe the potential in this technology and the possibilities coming with it as well as acknowledging the contribution from LIFE+. In March of 2014 the pilot plant was inaugurated by His Majesty, the Swedish King. Numerous other high-impact politicians and leaders in the energy sector have visited the plant both before and after the inauguration, including director-general of the Swedish Energy Agency and various leaders from companies in the energy sector.

The evaluation of the pilot plant and its installation consisted of several different components.

- The incoming material was verified regarding purity and composition
- The output from each machine was verified with different methods for different machines
- The final products were verified for efficiency using the custom-built equipment described in Report on Deliverable 4.1, and also for sustainability as described in Report on Deliverable 4.3, under section 8.2, Quality control.

The only other non-lab scale actor is GCell in Wales. GCell has under a number of years produced DSC commercially but with the limitations of their standard DSC they have not been able to become a large-scale actor. The GCell market potential is limited due in large part to their limitations in aesthetic configuration. They are limited to one design as seen below.



Above a comparison between the EXEGER dye-sensitized solar cell and the dye-sensitized solar cell from GCell. The whole area of the EXEGER cell (50% transparent) is active, to be compared with the lines of non-active area in between each cell in the GCell module. EXEGER produces a solar cell superior design and integration possibilities, opening up new markets and fulfilling broader customer demands. Integration of the EXEGER solar cell in new markets and products where light-weight, flexible, and aesthetically versatile solar cells have more potential, increases the positive impact on the environment, with more electricity coming from renewable energy sources.

The evaluation continues after the project ending in June 2015 and the continued success of the project, apart from having demonstrated the potential in November 2014, will be dependent on verified commercial interest in the form of a customer order.

5.2 Dissemination actions

OBJECTIVE
To document and rationalise our external communication efforts in conjunction with the LIFE + project. It will also serve as a guideline for communication strategies in future.

COMMUNICATION STRATEGY
To create a demand for transparent solar cells by creating awareness of the advantages of our technology and pointing out the possibilities.
This is done through various venues in an attempt to educate the scientific academia, research groups, policy makers, key decision makers from various governmental as well as market oriented organizations and finally at a later stage- the general public.

Media used for Dissemination:

Press releases: Official announcements of progress and news of Exeger.

Website: We have created a website (www.exeger.com), with the purpose of spreading information about DSC and our company's technology to the public online. A special page has also been created and dedicated to the LIFE+ project, explaining to the public about our project's mission to industrialize the production of transparent solar cells. The website has a sleek and clean design to convey a brand image of high tech commercial/industrial-scale company. There are also clear navigations and PDF information for download for ease and greater information retention. This website was re-launched in 2015 to further reflect the industrialization of the technology.

Conferences: Participation in various large international conferences associated with clean technology as well as dye-sensitized solar cells. This is a very important arena for meeting policy makers and important market decision makers.

Events: Exeger has been frequently invited by various government boards to share updates and capabilities about the DSC technology. This includes a roundtable discussion with US Secretary of Energy, Steven Chu. We also readily accept requests from universities and schools to share about the technology as well as tour our pilot plant.

Exhibitions: To raise the public's awareness about dye sensitized solar cells, Exeger has also participated in various exhibitions, such as "Top 100 Innovations" at Tekniska Museet and Ericsson's "Window of Opportunities" at Mobile World Congress 2013 in Barcelona, Spain and "New Tech Show 2013" at Svenska Mässan in Gothenburg.

Social Media: We have created an infographic video about the DSC technology and have uploaded it to Youtube in May 2013 to encourage viral sharing. The technical team of Exeger has also created LinkedIn profiles and will readily participate in the ongoing discussions regarding dye sensitized solar cells.

Printed media: We are, and will continue to produce printed materials to support our efforts in educating the public about the technology of transparent solar cells and the support of the EU-commission through the LIFE+ programme.

DISSEMINATION ACTIVITIES TO DATE

2010

Sep 2010

- 28 Sep 2010 – Press Release about Exeger securing SEK17.3 Million grant from the European Union LIFE+ project for demonstration of our DSC technology
- 29 Sep 2010 – Article in Ny Teknik

Nov 2010

- 4 Nov 2010 – Participation at the DSC-IC in Colorado Springs where important field knowledge was learned from leading experts in the DSC field helping the project in design of the pilot line.
- 16 Nov 2010 – Press Release about partnership with Fasadglas Backlin
- 16 Nov 2010 – Article in Dagens Industri

Dec 2010

- 20 Dec 2010 – Exeger featured in Deal Makers Monthly

2011

Apr 2011

- 8 April 2011 – Exeger featured in Ingenjörens

Sep 2011

- 7 Sep 2011 – Exeger's breakthrough 1DPC technology is being named by The Local as one of Sweden's Top Ten Technological Invention.
- 29 Sep 2011 – Attended Acreo Seminar in Norrköping

Oct 2011

- Printed first version of our brochure
- Printed roll-up banners
- 18 October 2011 – Exeger invited by Gothenburg University to comment on proposals from students regarding the various potential applications of our unique DSC technology.
- 23 October 2011 – Exeger invited to attend the Solar Arabia Summit in Riyadh, Saudi Arabia. This event was important to understand other solar technologies and adapt to the needs of the market. Mr. Robert Taflin was hired as a consultant for his knowledge of the real-estate market and his in-depth knowledge of Exeger Sweden AB which made him crucial for the visit to Abu Dhabi.

Dec 2011

- Launched our new revamped website

2012

Jan 2012

- Printed second version of our brochure
- 16 Jan 2012 – Exeger invited to attend World Future Energy Summit (WFES) in Abu Dhabi, United Arab Emirates. This is the world's foremost annual event committed to advancing future energy, energy efficiency and clean technology as a response to growing needs of sustainable energy where building integration is a crucial part of the solution. It will see over 25,000 attendees from over 130 countries. Mr. Robert Taflin was hired as a consultant for his knowledge of the real-estate market and his in-depth knowledge of Exeger Sweden AB which made him crucial for the visit to Abu Dhabi.

Feb 2012

- 24 Feb 2012 – Exeger participates in Tekniska Museet's 100 Innovations exhibition that spans over 3 years. We would be in charge of the Solar Energy exhibit and we currently have our infographic video on display.

Apr 2012

- Printed bulletin/notice boards for display on public premises
- 30 April 2012 – Attended Project Qatar, the 9th International Construction, Building, Environmental Technology and Materials Exhibition in Doha, Qatar. This trip was of utmost importance to understand the harsher conditions facades in the Middle East are exposed to in order to develop the capabilities of the printing lines for adaptation to all building integration market needs to increase the chance of success of the project.

May 2012

- As a part of the delegation of Their Majesties King Carl XVI Gustaf and Queen Silvia to South Korea, Exeger participated in the Korea- Sweden Innovation & Business Forum as well as the Yeosu Expo 2012. There, Giovanni Fili, CEO established contacts with potential suppliers and regulatory bodies with interest in bringing the DSC-technology to a global market.
- YouTube channel with infographic videos was created to educate the masses about DSC as well as Exeger's unique technology

Jun 2012

- Met with EPFL at Lausanne. The meeting allowed Giovanni Fili, CEO, and Henrik Lindström, CTO, to update the community of academia on Exeger's progress in industrializing DSC. Also, Exeger learned about the latest technological developments of DSC from the team at EPFL.

Aug 2012

- Met with business from the solar cell industry in Stuttgart, Germany to discuss potential collaborations and development.

Sep 2012

- Introduced the technology of dye sensitized solar cells and Exeger's core enhancement technologies to a group of architects in Oslo, Norway. The aim was to encourage this group of architects to design buildings that are more environmentally friendly.

Oct 2012

- All members of Exeger’s technical team have created LinkedIn profiles so they can readily participate in the ongoing discussions regarding dye sensitized solar cells and share knowledge to interested individuals.

Nov 2012

- Giovanni Fili, CEO, gave a seminar to a group of academia on designing sustainable architecture and buildings. He discussed about the possibility of installing transparent solar cells on glass facades to reduce buildings’ energy consumption.
- Participated in the Swedish-Indo Innovation Pavilion held in New Delhi, India. There, Giovanni Fili, CEO, had the opportunity to introduce dye sensitized solar cell as one of Europe’s most innovative clean technologies. The importance of the Indian market for success on a global scale would make the DSC-technology more attractive to Europen investors and increasing the chance for success of the spread of the technology.

Dec 2012

- Giovanni Fili, CEO, participated in a roundtable discussion with U.S. Secretary of Energy, Steven Chu. There, Giovanni shared Exegers’ cutting-edge clean energy solutions. The influence of U.S. Secretary of Energy in the global and European energy sector is invaluable to the dissemination project.
- Created a new promotional video about how DSC’s features and how it can be applied in the BIPV industry. Video was aired during World Future Energy Summit 2013.

2013

Jan 2013

- Created a new version of the corporate brochure, with the aim of updating the public about the latest developments of the project and the development plans. It was disseminated in the World Future Energy Summit 2013 and also at the Qatar Project, 2013 where global and European leaders of industry, government and education are present.

Feb 2013

- Collaborated with Ericsson in an exploration project titled “Window of Opportunity”, which was exhibited in the Mobile World Congress in Barcelona, Spain on 25-28 Feb 2013. The project aims to rethink windows, by turning them into transparent antennas, interactive display, or even transparent solar cells.

Mar 2013

- Giovanni Fili, CEO, and Henrik Lindström, CTO, represented Exeger at CleanEquity 2013, which was hosted by Prince Albert in Monaco. There, they had the opportunity to present about DSC and our enhancement technologies to C-level executives from top multinational companies from various sectors, including interest from the BIPV sector.

Aug 2013

- Giovanni Fili, CEO, visits EPFL and meetings with professor Michael Grätzel to update the community of academia on Exeger's progress in industrializing DSC.

Sep 2013

- Participation of the workshop on PVPS/BIPV at the Swedish Energy Agency for potential collaboration in a European BIPV project for sharing of expertise and combining different solution from different fields relating to BIPV.

Oct 2013

- Demonstration of the collaboration project "Window of Opportunity" by Ericsson and Exeger at the Swedish Embassy in Washington DC where key decision makers were in attendance.
- Presentation of the technology at the Swedish Energy Agency to professionals in the greentech industry as well as the German Ambassador for Sweden.

Nov 2013

- Giovanni Fili, CEO, held a seminar on the potential of the technology in the BIPV market to professionals invited by Akademiska Hus at the Royal Institute of Technology in Stockholm.
- 3 days of representation of the technology open to the public at the New Tech Show 2013 at Svenska Mässan in Gothenburg.

Dec 2013

- Giovanni Fili, CEO, informs the public about the progress of the technology at Material Dagen (materials day) at the Stockholms Mässan in Stockholm.
-

2014

Jan 2014

- Update of the progress of the technology at the Swedish Embassy in Abu Dhabi as well as the Future Energy Summit 2014, the world's largest energy convention. For success of the project, it is of utmost importance to keep the global and European industry informed of the progress and successes along the way.

Feb 2014

- Mr Giovanni Fili and Dr Henrik Lindström spoke at the Printed Electronics Europe where leaders of industry gather to learn about the newest trends in printed electronics.

Mar 2014

- Seminar at the Gothenbourg School of Economics held by Head of Business Development, Dr Georgios Foufas to lecture on the future of solar technology.
- Berlin

Maj 2014

- Attended and spoke at HOPV, the world's largest Hybrid and Organic PhotoVoltaic conference at EPFL, the birthplace of the DSC technology. 11 delegates from EXEGER took part to maximize dissemination impact.
- Meeting with industry London

June 2014

- Took part in the Swedish Cleantech tour in London.
- Attended the world’s foremost solar conference: Intersolar Munich
- Pitched at Ecosummit Berlin to a group of prominent financial institutions and industry.

Notable dissemination activities at the Exeger pilot plant:

As with any novel technology, demonstration is the key factor in convincing an audience of the demonstrated technology's potential. The finalization of the pilot plant and successful demonstration has enabled a more efficient and high impact dissemination. A lot of focus has been geared towards dissemination after the successful demonstration of the pilot plant at the EXEGER premises. Academia, government officials, leaders of industry, architects, have all throughout the project been invited to EXEGER for demonstration, this activity has increased dramatically during the months after November 2014. Some notable visits have been:

The Royal visit by the Swedish King HM Karl XVI Gustav
Erik Brandsma, the Director General of the Swedish Energy Agency
Thomas Ekman, CEO of Tele2 Sweden
Håkan Buskhe, CEO Saab AB and his staff
Christer Villard, Chairman of Wallenstam and their energy company Naturenergi
Jan Lindholm, CEO of Fasadglas Bäcklin AB
Chalmers University for project coordination of zero-energy projects
Janey Mehks, Business Development Manager at Stockholm Business Region
Business Development Department of the Swedish Energy Agency

AFTER LIFE COMMUNICATION

Every part of the project was a success. The pilot plant demonstrated and proved a production capacity of $50m^2$ per day during a demonstration period of 5 subsequent days. The world's largest solar cells where produced during this 5 day period and the pilot plan itself is unique globally.

After-Life communication is important for the success of the project. It is only after a successful demonstration the project can really take off and this is recognized in the communication strategy. Workshops and guided tours at the pilot plant have been and will continue to be held in the future. Dissemination will take place through attendance and presentations at similar events as during the ongoing project throughout Europe. The Dyemond Solar project homepage will be continuously monitored with contact information to the project coordinator at EXEGER.

As the global yearly capacity of the Dyemond Solar technology increases we expect the dissemination to also increase in success. This will in turn have a beneficial synergy effect boosting the awareness as increased capacity will translate into increased awareness and interest.

5.3 Evaluation of Project Implemention

Task	Foreseen in the revised proposal	Achieved	Evaluation	Cost-efficiency	Amendment effect
1. Project management and planning	Not affected by the extension of 15 months	Effective planning	Successful	Employing management experts with extensive project management experience led to cost cutting through elimination of the need for structural software and infrastructure	The more extensive and intense planning required for the new circumstances took place before the granted extension, in order to achieve success
2. Installation of the pilot production line	The foreseen result was the installation being reported June 2014	The achieved result was the installation being reported Oct 2014	Successful	Whenever possible, used machines were bought and modified for testing	Without the amendment the installation would not have been possible to complete during the project life-time
3. Demonstration of the pilot production line	The foreseen result was the demonstration being reported Nov 2014	The achieved result was the demonstration being reported Nov 2014	Successful	The demonstration task was running in parallell with the installation task in order to not loose valuable time and money	Without the amendment the demonstration would not have been possible to complete during the project life-time
4. Monitoring of Project and Demonstrations	The foreseen result was the final monitoring being reported Nov 2014	The achieved result was the final monitoring being reported Nov 2014	Successful	In-house monitoring was chosen given our experience from 6 Sigma	Part of the monitoring tasks was performed without the amendment but in order to monitor the installation and the overall project the amendment was absolutely necessary
5. Evaluation of EXEGER technology	The foreseen result was the evaluation being reported Nov 2014 and in the final report June 2015	One of the final steps in the evaluation was the demonstration of the pilot plan during the EU-representative in conjuction with the November demonstration week	Successful	Evaluation of the potential for the technology was mostly done at the pilot plant facilities with help from experts from varying fields including architects, industrial experts and others	
6. Dissemination	The foreseen result was 15 additional months of dissemination activities	The achieved result was the project being even more visible, for instance at the 2nd year in a row "Sweden´s 33 hottest technology companies"		Cost were cut wherever possible, for example through having inhouse design of printed materials, careful work regarding quotations and more	
Overall project				Methodology: Traditional approach for project handling. The steps utilized for all tasks were, in order, are requirement specification, planning, execution and validation. Cost-efficiency: The budget was adjusted with the extension and overall kept	

5.4 Analysis of long-term benefits

Before going deeper into long term benefits it is important to clearly state that the design of the pilot plant, along with the processes, management techniques, and machines have all been designed and optimized for long term success of the project. This has been done through modular design of most of the machines and pilot line allowing for simple scalability and reproducibility. Management style and techniques have also been optimized for an efficient structure and running of the pilot line. Modularity and reproducibility have been key factors in the design and implementation of the project.

Expected results points 1-7 pertaining lower production cost, increased energy efficiency, lower emissions and more environmentally friendly end products:

In 2010 Yingli Green Energy invested about 200 million Euro in a fully integrated mono-crystalline silicon based ingot, wafer, cell and module production line with an annual production capacity of 300 MW. That gives a rough estimate of about 130 million Euro for 200 MW annual capacity compared to a 200 MW fully integrated EXEGER DSC factory which would cost about 30-50 million Euro. That is, the investment cost is reduced by 60-80% using Exeger's DSC compared to using silicon based technology.

The 250 MW annual capacity production facility that First Solar built in Vietnam in 2011 had an investment cost of around 300 MUSD, which corresponds to 240 MUSD per 200 MW production capacity. In other words, the investment costs for Exeger's DSC is about 75-88 % lower compared to the mentioned thin film facility.

A state of the art 200 MW mono-crystalline silicon cell and module line from Meyer Burger in Switzerland had an investment size of about 90 million Euro in 2013. Adding the ingot and wafer production on top would give an investment cost far above that of Exeger's DSC technology.

The labour costs of a silicon or thin film manufacturing plant is roughly 1-2% of the overall production costs, comparable to the labour costs for Exeger's DSC. Using cheaper materials and an easy production technology with high level of automation that allow for scaling Exeger will easily reach a level with at least 50% lower operational costs compared to silicon and thin film solar cells.

The ruthenium, the electrolyte and the plastic components of the product are recyclable. More than two thirds of the weight of the product comes from the plastic materials used. The ruthenium and electrolyte are expensive components and therefore it makes sense to recycle them from a financial perspective. In total, the goal of reaching 50% recyclability is achieved by far.

Titanium dioxide is the naturally occurring oxide of titanium with chemical formula TiO2. The most common application areas are paints, sunscreens, food coloring, toothpaste, and in dye sensitized solar cells. Unlike silicon, it is environmentally friendly and abundant. Dyes which are also abundant are sintered onto the TiO2 particles, together forming the conductive layer of a DSC.

Photovoltaics has the potential to produce enough power to supply the world energy consumption needs. As mentioned earlier the solar energy reaching the earth's surface during only 6 hours is enough to meet all global energy needs on an annual basis. The potential in respect to global warming and CO2 emissions in using renewable energy as the main source of energy is well known. EIA estimates that about 21% of world electricity generation was from renewable energy in 2011,[1] with a projection for nearly 25% in 2040.[2]

The abundance of raw materials, lower embedded energy from production, and lower production costs demonstrated by the Dyemond Solar project increase the availability of solar power globally and if implemented can potentially increase the rate at which renewables are used as a source of energy.

World Energy Outlook 2014 shows nearly 1.3 billion people are without access to electricity and 2.7 billion people rely on the traditional use of biomass for cooking, which causes harmful indoor air pollution. These people are mainly in either developing Asia or sub-Saharan Africa, and in rural areas. Each year, 4.3 million premature deaths can be attributed to household air pollution resulting from the traditional use of solid fuels, such as fuelwood and charcoal.[3] Micro installations which would be more accessible with our light weight solar cells than traditional silicon glass modules could serve to reduce deaths associated with use of traditional solid fuels.

These are all solutions EXEGER and other stakeholders aim at tackling and work on making the DSC technology viable for all parts of the globe will continue throughout the company's lifetime. The modular design and the lower CAPEX of the factory will facilitate the spread of the technology. Scalability has been designed in most elements of the pilot plant for this specific purpose. As mentioned earlier, the management team with 6 Sigma experience has learned and developed along the way as the company has grown from 8 to over 30 employees. The development of the processes and standardizing relevant aspect of day to day work has evolved to efficient best practice methodology.

Benefits added through EU funding had a very positive impact on the credibility of the project overall. Dissemination has benefited from using the LIFE+ logo numerous times as crowds, academia, industry leaders and government officials associate the LIFE+ logo with projects of environmental relevance. Universities and other projects have also been keen on being associated with LIFE+ funded projects which has enabled further spread of the dissemination work.

A key long term indicator for measuring the success of the project is increased global production capacity. The pilot plant and its machines and processes have a modular design for reproducibility purposes. As the pilot line has proven a demonstration yearly production of 20 000m^2 it would be a success for the project if within 5 years the global production has increased to 120 000m2. That would be a reproducibility of more than 1 printing line per year. Long term, as dissemination work continues and successful printing lines are build we expect the increased capacity to grow exponentially.

[1] International Energy Statistics, Electricity, Generation (most recent data available on the date of this update)
[2] *International Energy Outlook 2013*, Chapter 5: Electricity, Figure 83. World net electricity generation by fuel, 2010-40
[3] http://www.worldenergyoutlook.org/resources/energydevelopment/modernenergyforallwhyitmatters/