LIFE Project Number

LIFE13ENV/NL/000971

FINAL Report

Covering the project activities from 04/06/2014 to 30/06/2020

Reporting Date

Definitief 30/10/2020

LIFE+ PROJECT NAME or Acronym

Solar Highways

Project Data

Project location	‘s-Hertogenbosch/ Uden
Project start date:	04-06-2014
Project end date:	30-06-2020
Total Project duration (in months)	73 months (including Extension of 0 months)
Total budget	€ 4.736.413
Total eligible budget	€ 4.736.413
EU contribution:	€ 1.404.837
(%) of total costs	50%
(%) of eligible costs	50%

Beneficiary Data

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2. Executive Summary

The main objective of the Solar Highway project is to demonstrate the technical feasibility and the environmental, social and financial benefits of using multifunctional constructive elements for building highway noise barriers, in which a bifacial PV solution has been integrated (with functionality independent of the highway direction). Solar highways helps to accelerate the use of PV and noise barriers along Europe's highways, contributing to achieve the EU objectives concerning climate change, noise and air. Integrating renewable energy sources into infrastructure will open up new economic opportunities.

The physical result of the project is a 400 m long prototype 5 m high noise barrier with 4 m high PV on both sides along a North-South stretch of the A50 near Uden. The primary function of this barrier is to protect people from noise. In the case of Solar Highways, the noise barrier is placed adjacent to a road next to a residential zone. In this way the inhabitants are protected from excessive noise levels.
In December 2018 the noise barrier with the integrated bifacial PV cells became operational. The official opening of the barrier on 18 February 2019, in presence of the Dutch Minister of Infrastructure, was an important milestone and gave the project a large media coverage. Solar Highways protects people from noise and produces renewable energy. Based on the monitoring results the yearly amount of generated electricity is estimated between 190 and 215 MWh. This is equivalent to the electricity consumption of 63 to 72 typical Dutch households[1]. Over the estimated lifetime of 30 years, the total generated electricity will be between 5.3 and 6.0 GWh and the avoided CO_2 emission is estimated between 2520 and 2850 ton[2].

Preparation phase
At the start of the project additional acoustic research was carried out between 25 August and 18 November 2014. This research showed that the intended location was not suitable for the project. After finding a new and better location near Uden along the highway A50, the project Solar Highways made good progress and the project end date could remain the same. The location near Uden was investigated and the necessary actions were determined. A benchmark study was carried out and a financial model was constructed. Other evasive actions were the development of a PV prototype, including producing and testing, and the preparation of the tender. The preparation phase was successfully completed with awarding the building contract in September 2017.

Implementation phase
The implementation of the PV noise barrier started in October 2017. First of all the prototype design was elaborated in a new design with PV-panels of 6 by 2 meters. The construction height of 5 meters is reached by a concrete panel (6 x 1 meters) with two PV-panels on top. Each panel consists of two equal sections of 3 meters wide and 2 meters high with strings of PV cells and junction boxes.
The bifacial PV cells were produced in strings of 8 and 9 PV-cells in China. These strings were connected to each other and to the junction and laminated between two glass plates.

[1] Based on an average yearly electricity use of 3000 kWh per household.
[2] Calculation based on the numbers from https://www.co2emissiefactoren.nl/lijst-emissiefactoren/

After extensive tests, the plates were fitted in a cassette with an aluminum frame and transported to the building site.
The first panels were placed in September 2018 in presence of the local and national press. In November 2018 all panels were placed and in December 2018 the installation was connected to the national grid. The production of solar energy started.

Monitoring phase
During the implementation phase an energy performance system was installed. The monitoring started in December 2018, immediately after the start of the energy production and ended 18 month later, in June 2020. The most significant result is the amount of energy produced.
Apart from the energy production, also the effect of different ways to carry out the maintenance were tested. It was concluded that cleaning the modules does not lead to a higher energy production. Therefore it is advised not to clean the modules from the perspective of maximizing energy performance.

Monitoring of the effect on air quality and noise levels is done using calculations. It is almost impossible to reliably determine the effect of the sound barriers by means of measurements. Therefore, in this situation, it has been chosen to determine the acoustic effects of the Solar Highways by means of sound calculation. Compared to a situation without a barrier there is a significant reduction in the noise levels and the legal standards are met. The area of noise levels above 50 dB is reduced with 75.000 m2 from 425.000 m2 to 350.000 m2.
The effects on the air quality is calculated for 18 locations, just behind the barrier. Comparing the situation without the barrier with the situation with a barrier, we see a reduction of the NO2 concentrations varying from 0,01 to 0,15 µg/m3 (yearly average), of the PM10 concentrations from 0,00 to 0,15 µg/m3 (yearly average) and of the PM2,5 concentration from 0,00 to 0,07 µg/m3 (yearly average).

Communication and sharing knowledge
Even more important than the physical result are the learning experiences and the demonstration of the technical feasibility. The project offered and will offer the possibility to gain experience with the participation of residents and the positive effects on the environmental management and image of Rijkswaterstaat as the national road authority. The core message for the project is formulated as follows:
Solar Highways is a project of Rijkswaterstaat (the executive body of the Dutch Ministry of Infrastructure and Water Management) aiming at the development of an innovative noise barrier, generating electricity and reducing noise levels. The prototype is a noise barrier of 400 meters long and five meters high that generates sloar energy on two sides, using integrated solar panels. A sustainable solution that produces energy for approximately 40 households. The construction of the screen starts in 2018. After completion the monitoring will start and last up to 2020.
This message was used to inform all stakeholders. Per stakeholder additional relevant information was added and gatherings were organized. At special moments such as the start of the energy production and the opening by the Minister a lot of positive publicity was generated, in newspapers, on radio, television and in social media. Other projects came to visit the location, municipalities from all over the Netherlands showed interest and the website was well visited. Meetings with residents and interested market parties were organized. A notice board and an information board were placed. Solar Highways published a brochure and placed two films on Youtube. Technical articles were written and published. In November 2019 a conference was held in which the making of Solar Highways was

extensively explained and in which the possibilities of exploitation and options for the future were presented.
As a result the communication objectives were realized. All relevant stakeholders are aware of the objectives, backgrounds and progress of Solar Highways. Exploitation, monitoring, communication and sharing of knowledge will continue after the end date of the project.

Projectmanagement
The project management consisted of a Partner Group and a Steering Committee in which all beneficiaries were represented. In a Partnership Agreement the organisation, responsibilities and other appointments between the partners were elaborated.
At the start of the project the originally foreseen location near Dordrecht appeared to be not suitable and another location had to be found. The project overcame this setback with success. The European Commission agreed with the solution and the new location near Uden. From this moment the project made good progress and all deliverables were realized without serious problems. All required reports were submitted and accepted in time. During the project, the end date was never adapted.

In 2018 it was necessary to ask the European Commission to amend the Grant Agreement because of a partner change and because of an increase of the costs. Especially the realization appeared to be more expensive: the contractor offered the realization for € 3,0 million, significantly above the estimate in de Grant Agreement of € 2,3 million. Above that the personnel costs exceeded the estimations in de Grant Agreement. With regard to the partners, an amendment was necessary because the partner ECN became part of TNO. The amendment was accepted by the European Commission and the Partnership Agreement was adapted to the altered situation.

After completion of the solar barrier in November 2018 the contractor was kept responsible for maintenance and cleaning until the end of the project in June 2020. This period of 18 months was used for monitoring purposes. In June 2020 the inspection and maintenance became the responsibility of the standing organization of Rijkswaterstaat. A separate contract was produced and put out to tender.

During the process special attention was paid to the exploitation of the solar installation. One of the objectives is to show the financial benefits and the social impact. To realize both objectives a lot of effort has been paid to lease the installation to a cooperation of residents living behind the barrier. This appeared to be very difficult. Rijkswaterstaat wants to keep sufficient control over the barrier to fulfil its responsibilities as a road authority and Solar Highways does not fit in the regulations of the Ministry of Finance. The efforts and meetings within Rijkswaterstaat and with the Ministry of Finance (owner of the state property and responsible for taxes) resulted in a lot of experience, but unfortunately not yet in a lease contract concluded with an cooperation. The produced electricity goes in the national grid and is taken into reduction from the overall electricity consumed by Rijkswaterstaat.
The efforts to involve the residents and to realize a better business case will continue.

After the completion of the project and the last payment an audit was carried out.

3. Introduction

Noise of roads and railways often causes nuisance to the residents living nearby. Noise legislation has obliged road authorities to erect noise barriers along roads and railways to reduce the hindrance. Research has shown that the barriers also have a positive effect on the air quality behind the screen. A conventional noise barrier already contributes to two environmental objectives.

Incidentally, we see that noise barriers are also used to attach solar panels and thus contribute to a third environmental objective: reducing CO2 emissions. This contribution can become a lot larger taking in account the number and surface of noise barriers. However, the practice is that road managers and energy producers often do not see the possibilities and are afraid of high investment costs and organizational risks. Solar Highways shows that the combination of noise reduction and power generation works. Solar Highways does this by integrating bifacial PV cells into the barrier. We have chosen for bifacial cells because the energy yield is higher compared to a standard cell and the noise barrier does not have to be orientated to the South. Bifacial cells make it possible to follow any road direction. The objective of integration of the PV cells in the modules of which the noise barrier consists, is also cost reduction. The same modules have three functions: noise reduction, air quality improvement and energy generation. In addition, the project aims to show that by involving residents there is an advantage for the road administrator, in management as well as in image.

The main objective of Solar highways is to demonstrate the technical feasibility and the environmental, social and financial benefits of using multifunctional constructive elements for building highway noise barriers, in which a bifacial PV solution has been integrated (with functionality independent of the highway direction). Successful demonstration will help to accelerate the use of PV and noise barriers along Europe's highways and contribute to achieving the EU objectives concerning climate change, noise and air.

Solar Highways has realized a 400 m long, 5 m high prototype noise barrier with 4 m high PV functionality on both sides along a North-South stretch of the A50 motorway near Uden. The noise barrier includes 1600 m2 of PV-modules with fully integrated bifacial PV cells. Solar Highways is searching for a way to make the energy yield available for the community living behind the barrier. Important issues such as ownership, maintenance and compensation (rent) are in development.

In the short and long term, the effect of Solar Highways is meeting the noise standards near Uden, enhancing the air quality behind the barrier, generating solar energy and contributing to the reduction of CO_2 emission. The long term effect can increase enormously if Solar Highways succeeds in accelerating the use of PV in noise barriers. Apart from the effects on climate, noise and air, this new type of noise barrier will open up new economic opportunities.

In this report information is given about the preparatory, implementation and monitoring actions. The communication and dissemination of knowledge is described and information is presented about long term benefits, project management and financial aspects.

4. Administrative part

4.1 Description of the management system

Management structure

Rijkswaterstaat, ECN and SEAC are the partners in the project. Rijkswaterstaat is the road administrator and designated as coordinator. Rijkswaterstaat provides the project manager and the chairman of the steering committee. In order to monitor the progress of the project, there are regular meetings of the partners, both in a project group and in a steering committee. The distribution of work has been agreed and stipulated in a Partnership Agreement, sent to the Commission in March 2015.

The project management team (PMT) is responsible for monitoring the progress of the project, for assessing risks and mitigating these, for the coordination of the Project and for preparing the steering committee meetings. The coordinating beneficiary takes care of organizing the meetings of the project management team and the steering committee.
The steering committee is involved in case of problems and risks with progress/budgets that cannot be solved by the project management team. Decisions in the steering committee are based on unanimity. The steering committee is the decision making body in the consortium of the Coordinating Beneficiary and the Associated Beneficiaries. The project secretary is provided by the coordinating beneficiary and is responsible for convening meetings and preparing the agenda and for producing written minutes of the meetings.

The RWS coordination team Solar Highways is responsible for the coordination of the project, the communication, the organization of the exploitation after implementation, the reports to the EU and the deliverables assigned to RWS. Due to a serious shortage of staff, Rijkswaterstaat had to set priorities for the entire organization in 2016. With regard to Solar Highways it was decided that the implementation of Solar Highways barrier will be carried out by the project team responsible for the noise reduction along highway A50 between the junctions Sint-Oedenrode and Paalgraven. Arrangements regarding the division of tasks between both project teams were formalized in July 2016. It was agreed upon that the project team responsible for the noise reduction will have the lead in the contracting and realization and will report to the RWS coordination team Solar Highways. The project team responsible for the noise reduction consisted of a project manager, project controller, contract manager, stakeholder manager and technical manager – all provided by the coordinating beneficiary.

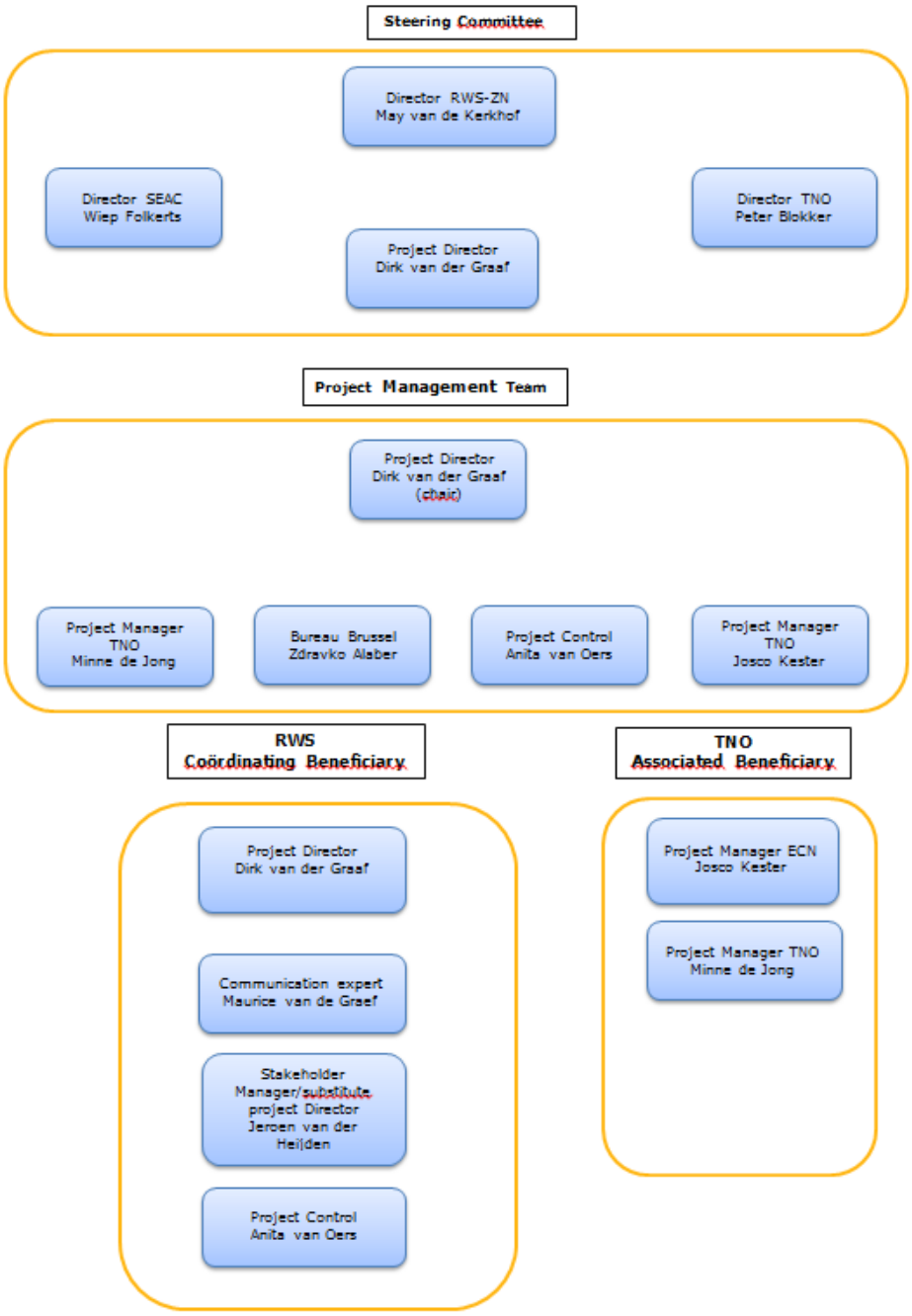
Amendment no 1 to the Grant Agreement.

In April 2018 a request for an amendment to the Grant Agreement was submitted. This became necessary because TNO and ECN had decided to merge per the 1st of April 2018 and to continue their sustainable research and development activities as "ECN part of TNO". For the Solar Highway project SEAC had been hiring up to 31st of March 2018 external assistance from TNO for execution of tasks in the project. This situation ended per 1st of April 2018. SEAC remains partner in the project.
Above that, the expected total costs of the project increased with € 908,224 to € 4.648.948. This did not endanger the project because Rijkswaterstaat has assigned sufficient budget to the project. Budget changes concerned personnel costs, costs of external assistance and the cost of infrastructure, prototype and equipment. In July 2019 the Amendment was signed.

The Amended Partnership Agreement between RWS, TNO and SEAC was signed in August 2019 and sent to the Commission. The financial agreements were updated.

Organization chart

The management structure has undergone several changes during the process, including several changes in the chair of the steering committee and changes due to the change of partner. The organigram below shows the actual structure. Note: initiator and project director Dirk van der Graaf retired in December 2019. Jeroen van der Heijden took over his role. Dirk van der Graaf wrote the main part of the Final Report. The new contact person for the Commission is Eric Boessenkool.



Management actions

To organize the project the following activities were executed:

- Project management team meetings (PMT): 24-7-2014, 11-9-2014, 26-11-2014, 11-2-2015, 18-5-2015, 1-10-2015, 3-3-2016, 2-6-2016, 13-9-2016, 23-3-2017, 26-10-2017, 29-3-2018, 1-11-2018, 28-2-2019, 23-10-2019.
- Steering committee meetings: 10-12-2014, 19-1-2015, 8-6-2015, 9-6-2016, 16-5-2017, 1-11-2017, 11-7-2018, 14-11-2018, 28-3-2019. The alderman of the municipality of Uden took part in the meeting of May 2017.

Project phases

The *preparation phase* of Solar Highways consists of:
Preparation of the realization: performing a benchmark study, location research, prototype design, building a technical financial model, determining possibilities of operating, determining a procurement strategy and preparing the tender documents. This part of the preparation started in April 2014 and was completed in September 2017 with the awarding of the construction contract. The preparation phase was completed and the *implementation phase* started. This phase mainly consists of designing and constructing the barrier with the PV-modules and ended with the transfer to the highway administrator in June 2020. An important milestone was the placement of the barrier by the end of 2018 and the opening in February 2019 by the Minister of Infrastructure, Water management and Environment. The *test and monitoring period* started in December 2018 and ended in June 2020. The *exploitation phase* is not part of the Life project.

4.2 Evaluation of the management system

Challenges

The management of the project was without major problems. The main issues concerned the change of location, the internal decision-making at RWS (deployment staff, final decision) and the required amendment. All these issues were solved.

The challenges were many as could be expected with an innovative project. In the preparation phase a lot of attention was needed for the design of the prototype and the preparing of the tendering. At the start of the project, the idea was a procurement strategy whereby construction and operation were combined in one contract. After consultation of market parties and energy suppliers, this was abandoned because of too many uncertainties. The challenge in the implementation phase was optimizing the design and producing the huge panels of 2 by 6 meters with the bifacial modules laminated between glass plates. Organizing the operational phase appeared to be the most complex challenge. Solar Highways is a novum within the assets of Rijkswaterstaat. Experience has to be gathered about maintaining the electronic part, about graffiti and vandalism etc. Finally it was decided to tender a maintenance contract with a duration of approximately 3 years, excluding major maintenance. As the exploitation was excluded in the tendering, a separate process started to organize the exploitation, including the involvement of residents. The goal of this process is to found a local energy cooperative and to lease the installation to this cooperation.

Conditions of Rijkswaterstaat as highway authority are:

- secure management and maintenance (finance and staff)
- comply with the legal noise standards
- do not unnecessarily impede any future road modifications.

Additionally, the Commission has conditions regarding commercial use of prototypes developed within the framework of the Life + program.
Until this goal for the operational phase is reached, Rijkswaterstaat takes care of the exploitation and the solar energy is for Rijkswaterstaat own use.

Reporting

Since the start several reports have been delivered to the EU: Inception Report (12-3-2015), Additional information to the Inception Report (9-6-2015), 1st Progress Report (20-06-2016), Midterm Report (21-12-2017) and 2nd Progress Report (28-03-2019).

Project Visits

Project visits by the EU-monitor took place on: 26-11-2014, 10-12-2015, 24-11-2016, 18-5-2018, 18-2-2019 and 30-4-2020. The visits were confirmed and evaluated in the letters from the Commission. Apart from the visits, there have been regular contacts between RWS as a coordinating partner and the monitor appointed by the Commission. These contacts were very useful and helped the project team to fulfil the EU requirements.

5. Technical part

5.1. Technical progress, per task

5.1.1 Action A1 Location research

Responsible: Rijkswaterstaat

Additional acoustic research conducted between 25 August and 18 November 2014 showed that a significantly smaller noise barrier is required at the location proposed in the Grant Agreement. This meant that the project team had to look for a different location and that the ongoing investigation into the location at Dordrecht could be stopped. As a result, a delay has occurred and the planning of the entire project has been adjusted. An important adjustment was the reduction of the monitoring period from 27 to 18 months, a better match between the results of actions A3 and A4 and the start of the tender. This is reported in the Inception Report. Attachments to the Inception Report were the Memo *Afweging geluidsmaatregelen locatie Dordrecht* and the *Location selection plan*. On April 10, 2015, the EC accepted the proposals for adjusting the planning.
The search for a new location ultimately resulted in a decision by the steering committee to continue the Solar Highways project at a location along the A50 near Uden. On June 9, 2015, the project manager Solar Highways reported to the EC on the decision of the steering committee in addition to the Inception Report. In the letter of 6 July 2015, the EC indicated that the project can continue and that the additional costs incurred are eligible.

Figure 1: Location Uden

The project team A50 Sint-Oedenrode - Paalgraven is responsible for improving all noise measures along the A50 motorway between the junction Paalgraven and the junction Sint-Oedenrode. This team has determined and investigated all locations on this route where noise measures are required. The research was carried out on behalf of the project team A50 Sint-Oedenrode - Paalgraven. The costs are therefore borne by that project. The research provided insight into the required noise reduction, soil condition, flora and fauna, archaeological values, explosives and cables. The results of the investigations were part of the tender documents.

For the location Uden, the noise survey conducted by engineering firm Royal Haskoning / DHV has shown that the ground level used in the original acoustic survey carried out before constructing the A50, was too low. The actual ground level location is higher and the estimated effect of the barriers built is therefore overrated. For the existing houses the noise loads of the actual realized facilities have been calculated. In total there were 13 homes with noise levels above the legal standard. The effects were calculated of heightening the existing noise barrier of 4.0 meters high with 1.0 meter over a length of about 91 meters and with 2.0 meters over a length of about 331 meters. Based on these investigations Rijkswaterstaat decided to replace the existing screen near Uden with a new 5 meter high barrier.

In June 2015 shadow measurements were performed by SEAC which showed that the location is perfectly suitable for the Solar Highways project. Also in 2015, the Solar Highways project team made an inventory of stakeholders and required permits. On October 4th, 2016, the inhabitants (about 400 addresses) were informed by a letter from the municipality of Uden. They also received the Solar Highways brochure. On October 12th, 2016, a press release was sent out by RWS. All research and results have been summarized in the final report *Action A1 Location Research* (Ref. 1). This report was completed in January 2017. This is considerably later than originally planned: February 2015. This delay is caused by the change of location and also by the late final implementation decision of Rijkswaterstaat. This decision was taken on 30 June 2016 on the basis of the final estimate for implementation and closing financing. It was considered not to be proper to inform all stakeholders before this decision.
However, based on the existing information, the preparation of the tender continued awaiting this decision. Therefore, the delay in completing Action A1 did not affect the project end date.

5.1.2 Action A2 Benchmark study

Responsible: SEAC

The benchmarking study presents an overview of known initiatives for photovoltaic noise barriers (PVNBs) in Europe, to be able to learn from past failures and successes and provide input for the development of the techno financial model (action A3) the PV integration design (action A4) and the procurement strategy, procedure and evaluation (action A5). The study focuses not only on technical aspects, but also provides background information on financial and organisational issues. A number of installations across Europe have been studied in more detail in literature and by visiting the installations and the designer, builder or owner of the installation.

The benchmark study has delivered recommendations on the design of the noise barriers with PV systems, monitoring, shadowing, safety and security, vandalism and theft, ownership and responsibilities, cleaning, procurement strategy and stakeholders.

Action A2 started August 2014, four months later than planned due to general start-up problems. In December 2014 a draft version of the report was presented to the project management team. The final report, *Solar Highways Benchmark Study* (Ref. 2.), was completed in January 2015.

Country	City	Road/Railway	Rated power (kWp)	Tilt	Azimuth	Year	Location known	Material	Owner/Builder
Switzerland	Chur	A13	100	*45°*		1989		c-Si	TNC AG
Austria	Seewalchen	A1	40		*160°*	1992			Oberöstereichische Kraftwerke
Germany	Rellingen	A23	30		*200°*	1992			TST (DASA)
Switzerland	Gordola	Rail	103		*200°*	1992	X		TNC AG
Germany	Saarbrücken	A620	60			1995			Stadtwerken Saarbrücken
Switzerland	Giebenach	A2	100	*45°*		1995			TNC AG/ Kanton Basel
Netherlands	Utrecht	A27	55	50°	245°	1995	X	c-Si	RWS
Netherlands	Ouderkerk a/d Amstel	A9	220	50°	200°	1996	X	c-Si	Shell & ENW / EU Commision
Germany	Inning am Ammersee	A96	30			1997			TNC GmbH, Bayernwerk, BMFT
Switzerland	Zurich (Aubrugg)	E41	10	90°	*80°*	1997	X	c-Si	Uitbreiding door TNC in 2004
Switzerland	Zurich (Walliselen)	Rail	9.6	*45°*	200°	1998	X	c-Si	TNC
Switzerland	Zurich (Brütisellen)	A1	10	90°	*140°*	1999	X	a-Si	TNC
France	Fouquières-lès-Lens	A21	63	*45°*	*170°*	1999	X	c-Si	
Germany	Sausenheim	A6	100			1999			
Austria	Gleisdorf	A2	101			2001			
Switzerland	Safenwil	A1	80	*45°*	*170°*	2001	X	c-Si	IG Solar Safenwil
Germany	Emden	A31	53	90°	180°	2003	X	multi	Straßenbauamt Aurich/Energievers
Germany	Freising (Munich)	A92	600	*45°*	*180°*	2003-	X	c-Si	
Germany	Vaterstetten	Rail	180		*210°*	2004		a-Si	Phoenix Solar
Germany	Freiburg	B31	365			2006			TNC, aluminium: Van Campen
Germany	Großbettlingen	313	28			2006			
Australia	Melbourne	40	24	90°	180°	2007	X	a-Si	
Germany	Töging am Inn	A94	1000	*45°*	*210°*	2007	X		
Switzerland	Melide (Lugano)	A2/rail	123	*45°*	*220°*	2007	X	c-Si	Suntechnics Fabrisolar AG
Switzerland	Münsingen	Rail	14	90°	*80°*	2008	X	c-Si	TNC
Italy	Marano d'Isera (Trento)	A22	730	*	*140°*	2009	X	c-Si	IrisLab/Autobrennero A22
Germany	Aschaffenburg	A3	2065	45°	*150°*	2009	X	c-Si	Evergreen solar GmbH
Italy	Oppeano (Verona)	SS434	833	45°	*210°*	2010	X	c-Si	
Germany	Bürstadt	B47	283	60°	*150°*	2010	X		
Germany	Biessenhofen (Bayern)		90	*45°*	*180°*	2010	X		Rau Lärmschutzsysteme
Germany	Wallersdorf	A92	1000	*45°*	*150°*	2010	X		Apfelböck Ingenieurbüro GmbH
Germany	Polling	Rail	1200	*45°*	*210°*	2012	X	c-Si	Exaphi GmbH
Germany	München	Rail/road	7.5	90°		2013			Kohlauer
Switzerland	Zumikon	Road	90.8	*45°*		2014		c-Si	TNC
Systemens in preparation									
Netherlands	Bathmen	A1	*1000*		*180°*				RWS
Netherlands	Tiel	A15	*300*						
Germany	Michendorf	A10	4500		*180°*				
UK	Swindon	A419							
UK	Buckinghamshire	M40							
Netherlands	Rotterdam	A20							

Figure 2: An overview of existing and planned PVNBs in Europe, including key characteristics. Estimations are *italic.*

5.1.3 Action A3 Technical financial model

Responsible: SEAC.

A techno-financial model in Excel format has been produced that covers investments and operational expenses as well as legislative regulations like net metering, in order to give an assessment of return-on-investment (RoI) and payback time. The Excel calculation model gives an assessment of return-on-investment, Net Present Value, Levelized cost of electricity and payback time for certain combinations of investment costs, kWh price, O&M costs and financial parameters. The model can estimate the price of PVNB-specific PV modules, now and in the near future and both calculates the price of these modules per Watt-peak (Wp) and per square meter. Awaiting more accurate electricity yield predictions, an assessment had been made of expected energy yield for the projected Solar Highways Photovoltaic noise barrier at the Uden location.

Together with the other beneficiaries SEAC has chosen a number of feasible business models for the Solar Highways Project. Some of these models include national subsidy and fiscal regulations. By combining the calculation model, the pricing model and the technical assumptions, SEAC has calculated cash flow schemes, return-on-investment, Net Present Value, Levelized cost of electricity and payback-time. SEAC shared these findings with the project team via presentation at PMT meetings and by producing a report 'Solar Highways: Wat levert het op?'. For the current situation, only the scenario where customers receive a tax benefit over a 25-year period, there is a return of the investment. The payback period is calculated at 21 years. For scenarios in the near future, the situation is more favourable because of higher returns and lower investment costs. In the most favourable scenario, the investment is payed back in 8 years.

The results of Action A3 were input for the tender documents as part of Action A5.

Action A3, the drafting of a technical financial model started on January 28, 2015. It was initially stated that the technical financial model will be validated on the basis of the monitoring results after the PV noise barrier has been placed. Because this validation is also included in Monitoring Energy Performance and Reliability, Verification Techno-Financial Model and Overall Evaluation Report (Action C2), the results are summarized in the report, *Action A3: Techno-financial model* (Ref. 3).

5.1.4 Action A4 PV Integration design

Responsible: ECN.

The first prototype was completed in March 2016 and presented at the Innovation Expo and at a meeting of EU ministers, 14 April 2016 in Amsterdam. In October 2016 full size outdoor tests started.
The second prototype was placed at the ECN premises and used for outdoor monitoring since October 2017. The design was used as a reference design during the tender procedure in 2017 and included as one of the tender documents. The yield measurements of the prototype continued to the end of the project and are compared with the monitoring results of the Solar Highways barrier in Uden. The results of these measurements are presented and analysed in Action C2- Monitoring energy performance and reliability, verifying techno-financial model and overall report.

The final report on the design of the integratable bifacial module with results on quality and lifetime was completed in April 2019. The final report and its annexes give full information about the design process, tests and results: *Action A4*: *PV Integration design* (Ref. 4). Preliminary results have been presented at EU PVSEC 2017 conference.

<u>Results</u>
The results of this action are:

1. Proposed design of the bifacial PV element
2. Quality and lifetime demonstrated by IEC test results
3. Performed (yield) measurement of created integratable module
4. Proposed design for electrical system interconnect.

<u>Proposed design of the bifacial PV element</u>
The design of the bifacial laminate design was derived from modelling, taking into account shading by the support construction. Tilt, barrier orientation and dimension of the support construction were varied to study the effect on the energy output of the barrier. The interconnection of the solar cells was optimized to minimize the effects of shading. This resulted in 6 strings per 6x1 m barrier element. The final system design consists of 3 of these 6x1 m elements in a row, 4 on top of each other. The 2 top rows are connected in series to an inverter, as are the 2 bottom rows. This design has a lot of cables and therefore quite high resistive losses. An alternative of 6x2m elements is proposed, but currently this cannot be manufactured. Damp heat and thermalcycling tests show that the panels comply with IEC standards. Graffiti tests did not reveal a promising solution, but results from a subsequent project showed that when a commercial anti-graffiti coating is used, the graffiti can be easily removed by warm pressurized water. The panels that are finally produced for the prototype noise barrier have an output of 18.5 W/m2.

Figure 3: First prototype

Figure 4: Final test setup in Petten

The first 1x3 m working prototype was constructed and presented to the project team and at the Innovation Expo in Amsterdam (14 April 2016). This specific prototype has been used to verify and further refine the outcome of the modelling tool and for outdoor measurements. A full size 6-meter element was built in Q1-Q3 2016 and installed at ECN in Q3 for outdoor durability and performance measurements. This prototype element has demonstrated that the 1x6 m element can be integrated in a MGS and was used to test the design of the electrical integration.

<u>Quality and lifetime demonstrated by IEC test results</u>

Damp Heat Tests

One of the IEC tests contains damp heat (DH) and thermal cycling (TC) testing. During DH testing the panels are subjected to a relative humidity of 85% at a temperature of 85°C for 1000 hours. For these tests, smaller laminates are used that were built using the same process and the same bill of materials as the large prototype. The results are shown in Figure 5, where each point is the average change in output power of 3 laminates. For passing the IEC test, the power output should not drop more than 5% after 1 IEC test. As can be seen in Figure 5, the panel passes this test easily and does not even reach this limit after 5 times IEC, although a slight drop in power output is starting.

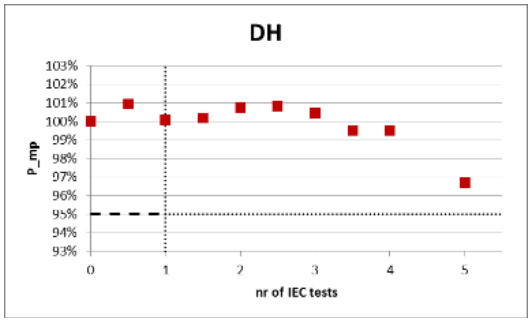


Figure 5: Relative change in power output after damp heat tests. Each point is the average of 3 laminates

Thermal cycling tests

The IEC test also contains thermal cycling tests, where the panel is subjected to 200 thermal cycles that go from -40°C to +85°C. Again, the power output should not drop more than 5% after 1 IEC test. As can be seen in Figure 6, the panel passes this test easily and does not even reach this limit after 5 times IEC, which corresponds to 1000 cycles.

Based on these results, the quality of the prototype is expected to be more than sufficient for use in a noise barrier.

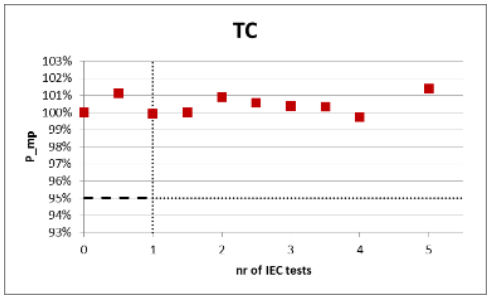


Figure 6: Relative change in power output after thermal cycling tests. Each point is the laminates average of 3 laminates

Graffiti tests

Various glass samples with coatings have been treated with black spray paint, mimicking graffiti. It was shown that coatings do not decrease the adhesion of the spray paint to the glass nor improve cleaning. Dry cleaning and cleaning with water proved to be difficult, though a cleaning solution containing ethanol (alcohol) removed the spray paint quite easily. However, the use of ethanol for large surfaces along roads might not be suitable. Based on these experiments an alternative solution was tested in the TKI SONOB (Project TEZG114009), where a large graffiti was sprayed on a noise barrier element. The conclusion is that if the noise barrier is treated with an anti-graffiti coating, the graffiti can be removed easily with pressurized warm water.

<u>Performed (yield) measurement of created integratable module</u>

The yield of all produced laminates was measured by the manufacturer and by ECN. The measurements correspond within 2%. One prototype was used to measure the effect when covering the ground directly surrounding the module with different materials that reflect the sunlight in different amounts. The results are shown in Figure 7.

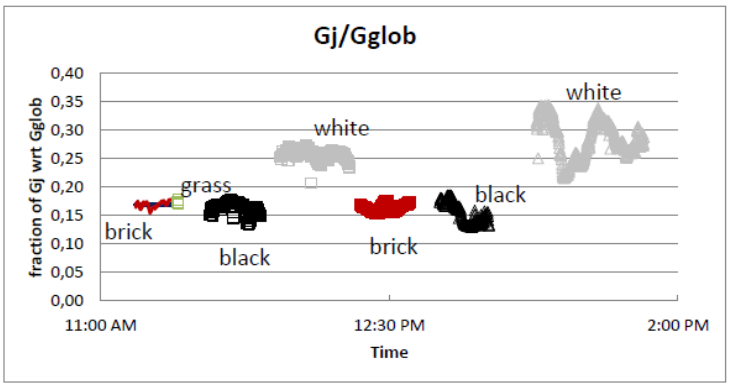


Figure 7: Fraction of irradiance on the rear for different albedo: ground (brick road), grass, black and white.

The other prototype is used for the outdoor measurements that started in October 2016. This monitoring shows that the panels generate roughly 637 kWh per element of 6x1 m when connected to an inverter with an efficiency of 0.96. A 4 m high barrier of 400m length could thus generate 169.9 MWh/yr. This is roughly 10% lower than the estimated of 187.2 MWh/yr based on PVsyst calculations, see report "Design considerations of a solar noise barrier" and is due to the large inverter losses of the prototype. Assuming an average energy consumption of a household of 3.3MWh/yr, it is estimated that about 51 families can be supplied by this 400m noise barrier. The yield strongly depends on the shading by the construction. The shading loss in the prototype is estimated to be 30% on a sunny day. The yield can be improved by improving the albedo. This can be done e.g. behind the noise barrier such that traffic is not affected.

Fig. 8 shows some results: the total irradiance on front and rear, corrected for the bifaciality factor, of the prototype, together with the normalized DC power output. In the morning the power output rises linearly with the rising irradiance, but around 10 AM it drops to a plateau. This drop in power is much faster than the drop that is expected due to the reduction in irradiance in the same period. Also shown is the DC voltage and current. The DC voltage stays rather constant over the day. Only a small drop is seen in the afternoon due to the rising module temperature. The trend in power output is almost completely governed by the current. The drop in current is caused by shadow from the construction bars that start falling onto the cells.

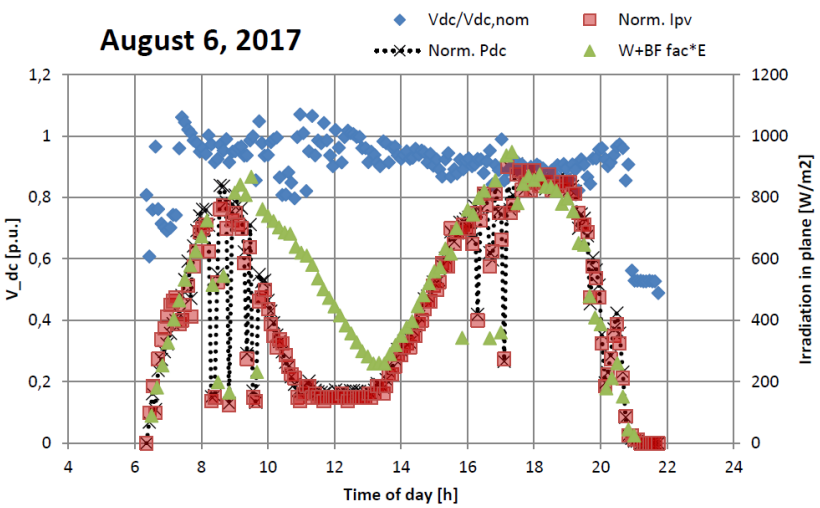


Figure 8: Output data of the prototype noise barrier on the test site in Petten. Normalized DC voltage, Normalized current (Norm. Ipv), normalized DC power (Norm. Pdc) are shown together with the in plane irradiance, corrected for the bifaciality factor on the rear (W+BF fac*E).

The final module design for the modular noise barrier consists of two 3x1m PV laminates. The sets are a mirror of each other with respect to the cell and bypass diode positions. Cells are placed as much as possible in the lower right and lower left of the PV laminates to minimize the construction-shading losses caused by the poles and beams of the support construction. This resulted in the design of Figure 9. For the support construction a standard modular noise barrier design was used.

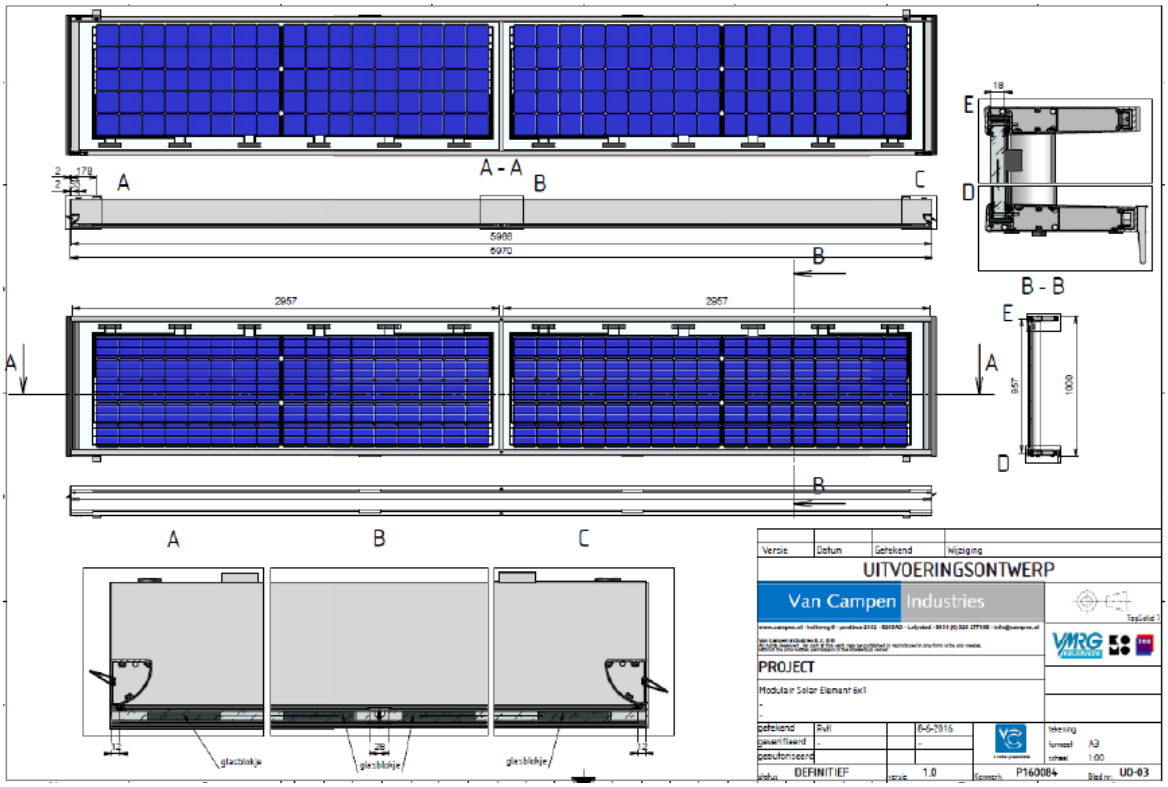


Figure 9: Final module design

5.1.5 Action A5 Procurement strategy, procedure and evaluation

Responsible: RWS.

Planning

The start of this action was foreseen in the Grant Agreement in March 2015 and the end one year later, May 2016. There has been a substantial delay caused by delays in actions A1, A3 and A6. The delay did not affect the end date of the project. Eventually, this action was completed in September 2017 with the awarding of the building contract.

Phases

The Grant Agreement indicates that Action A5 Procurement Strategy, Procedure and Evaluation includes three phases:

1. Procurement strategy plan
2. Innovative procurement procedure
3. Evaluation.

These phases are elaborated as follows:

1. Plan for the procurement strategy
2. The procurement
3. Awarding the contract.

Plan for the procurement strategy

Starting point for the market strategy was that design and construct will be put on the market according to either a Design & Construct or an Engineering& Construct contract. Given the innovative nature of the project, more integrated contract alternatives are explored. In May 2016 Rijkswaterstaat consulted the market in order to actively involve them in this early stage before the proposed tendering procedure would begin.

By undertaking this market consultation, RWS intends to gain an understanding of:

- the constraints within which the project can be successfully contracted and implemented;
- the experience of market players with the type scope of the project;
- the enthusiasm of interested, qualified market players for carrying out the project;
- the feasibility of the current time schedule;
- to assess the feasibility of the functional requirements and gain a greater understanding of meaningful MEAT[3] criteria.

After the consultation, it was decided to limit the contract to design, construct and maintain for 1,5 year after completion. The exploitation is excluded because of the many uncertainties. This implies a separate action: organizing the operation phase. This action will be part of Action E1, Overall project management. Furthermore it was decided to use optimizing the system and the maintenance as MEAT criteria.

After the market consultation, the contract documents were finished by Rijkswaterstaat. This included the elaboration of the MEAT criteria, inventorying all demands and translating them in contract requirements. All relevant demands of the Life+ program are integrated in the

[3] The most economically advantageous tender (MEAT) criterion enables the contracting authority to take account of criteria that reflect qualitative, technical and sustainable aspects of the tender submission as well as price when reaching an award decision.

contract. ECN and SEAC provided the specific requirements for the solar installation and the monitoring equipment.

Procurement

In January 2016 Rijkswaterstaat announced the contract Realiseren Geluidmaatregelen Sint-Oedenrode - Paalgraven en Solar Highways on Tenderned. First step is a search for suitable candidates. This resulted in five interested and qualified companies and five offers. Part of the procurement are information meetings and answering specific questions. In July 2017 Rijkswaterstaat received five plans for the Solar Highways project. The plans describe the way the candidate firm will realize the project, including the way to optimize the system and the maintenance. One of the plans did not meet the requirements and was no part of the evaluation. The other four plans were evaluated out by experts of Rijkswaterstaat according the previously announced criteria. After finalizing the evaluation on the quality, the financial part of the offer is opened and involved. This finally resulted in the best offer: the combination of Heijmans, Scheuten, Van Campen/Bayards and Libra. The contract sum amounts € 2.476.783 (without VAT). This exceeds the former estimates. The funding of Rijkswaterstaat is sufficient to make awarding the contract possible.

Awarding the contract

The awarding decision was published in September 2017 and after the Alcatel period the contract was signed in October 2017.

Action A5 is extensively described in the report, *Action A5 Procurement strategy, procedure and evaluation* (Ref. 5).

5.1.6 Action A6 Defining requirements for connection to electricity grid and energy performance model

Responsible: RWS

Planning

The start of defining requirements for connection to electricity grid and energy was originally planned to commence in May 2015, however due to the delays caused by the exploration for a new pilot location its start had to be postponed to September 2015. The connection of the PV-modules to a local energy grid requires location-based input, which could only be acquired once the new pilot location was identified. Because the new location at the A50 near Uden was deemed as a suitable location the Action was started and completed, according to the revised planning, in September 2015.

Results

The results of this action consist of two parts. The first part describes how the PV modules can best be connected to the power grid and the conditions for this connection. The information of this part of the deliverable is collected through discussions with the energy grid company.

The second part contains several exploitation models. SPPS was contracted to assists in defining the requirements and the energy performance model. This resulted in a report (December 2015) that showcases how the PV-modules can be connected to the local energy grid and which prerequisites have to be considered for the connection between the PV-modules and the energy grid. The technical information has been acquired via consultation talks with the project partners and by combining this qualitative input with available data/information regarding energy yields, grant regulations.

The report describes:

- which entities are involved in the production and consumption of electricity;
- the kind of organisations that are involved in the daily operations;
- the legislative, organisational, and tax structure that are required to recoup some of the investments.

This Action provided input for the procurement (strategy) of the works in Action A5 and the energy performance model. It is also related to Action A3 in which the Techno Financial model has been formulated.

5.1.8 Action B1 Development, production, implementation and use of PV noise barrier

Responsible: RWS

The implementation of the PV noise barrier started in October 2017 after completing the procurement. Action B1 consists of the sub actions B1.1 *Development, testing and production of the noise barrier with integrated PV*, B1.2 *Erection of the noise barrier* en B1.3 *Maintenance and cleaning.* The PV noise barrier was completed in December 2018.

Design

The design principles and the general design were made in the period October 2017-February 2018. In the design process computer simulations were used to analyze and minimize the effects of shadowing by the construction itself. The result is a design with PV-panels of 6 by 2 meters. The construction height of 5 meters is reached by a concrete panel (6 x 1 meters) with two PV-panels on top. Each panel consists of two equal sections of 3 meters wide and 2 meters high with strings of PV cells and junction boxes. The layout was greatly determined by the condition to minimize the effect of the non-avoidable shadowing. If one PV-string falls out, the bypass diodes in the junction boxes ensure the working of the remaining PV-strings. Each section has two optimizers in the top rail. The optimizers provide optimum revenue by the optimum between amperage and voltage. All cables and electronics are out of sight and hidden away in the construction. The optimizers are connected to invertors were the direct current (DC) is transformed in alternating current (AC). The invertors are situated in two separate stations. These stations are connected to the national electricity grid. In one of the stations are instruments to measure the yield per section. Failures can be signaled easily.

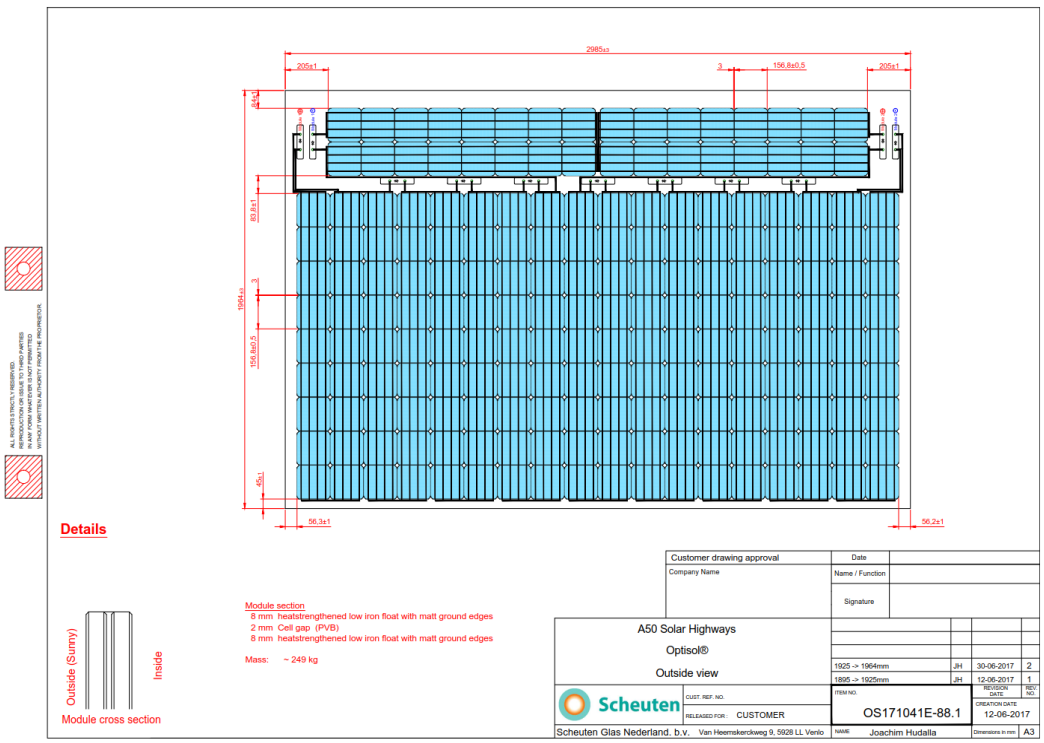


Figure 10: Section details

In the Final Design phase, the main support structure was calculated and drawn, consisting of the superstructure styles, the anchoring and the foundations. With calculations and constructive considerations it was proven that the structure can withstand the prescribed loads under all prescribed conditions. The design of the glass screen panels with solar cells falls within the scope of the supplier (construction phase and final phase consideration). Last step in the design process was to elaborate the final design in detailed drawings for the implementation and the verification of all demands in the contract with Rijkswaterstaat.

Detailed design drawings, overviews of the electronic part of the construction and verification reports can be found in the archive of the project Geluidmaatregelen A50 Sint-Oedenrode - Paalgraven.

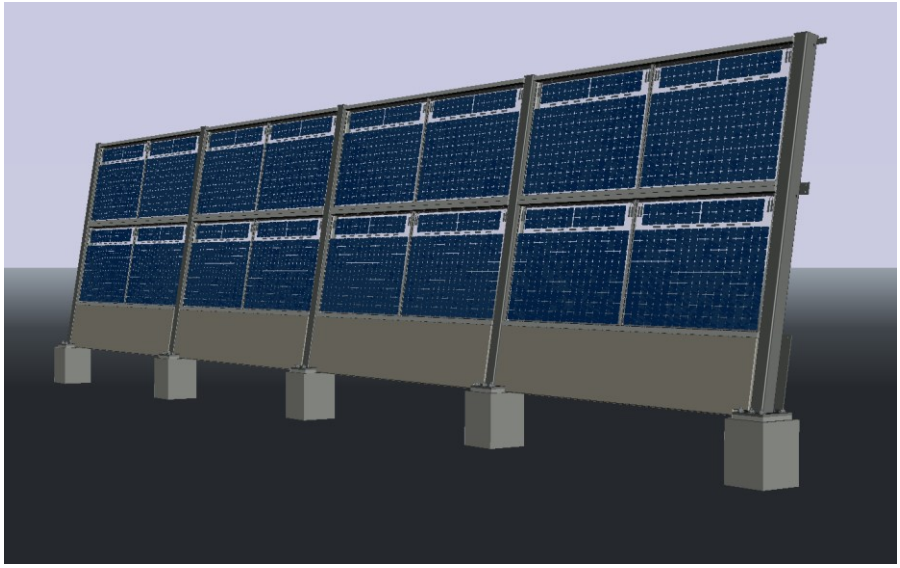


Figure 11: Final design

Production and testing

The bifacial PV cells were produced in strings of 8 and 9 PV-cells in China. At Scheuten Glas in Venlo these strings were connected to each other and the junction boxes according the design and after that laminated between two glass plates of 2 by 6 meters. These plates were extensively tested. After the last tests, the plates were transported to Lelystad and fitted in a cassette with an aluminum frame. Each cassette has an unique number to which all tests can be related. Finally the cassettes with the panels were transported to the construction site in Uden. The complete Solar Highways PV system was tested before it was connected to the grid.

With the production of the panels, Scheuten Glas won the national Glass Award 2019.

Figure 12: Strings from China

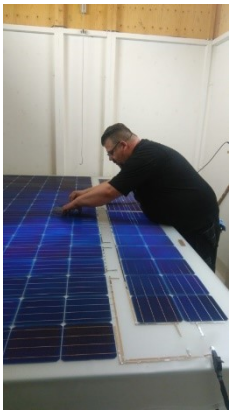


Figure 13: Production at Scheuten

Erection of the noise barrier

Before the actual erection the contractor carried out several activities such as:

- Elaborating planning, management plan, safety plan, flora and fauna plan
- Obtaining permits
- Surveys (soil, explosives, cables, pipes)
- Removing obstacles
- Setting up the building site
- Placing the building boards
- Informing local residents

The existing barrier was removed in June 2018. To minimize traffic disruption this was done in night shifts. Local residents were informed in advance about the activities and the period without a noise barrier. As a result there were no complaints.
After the removal, the foundation was constructed and in the weeks 33 until 40 the construction was completed. Every 100 meter a plaque with the Life logo was attached to the construction. The first panels were placed on the 13th of September in presence of the local and national press. In November 2018 all panels were placed. Part of the panels is connected to station A and part of the panels is connected to station B. In these stations the direct current (DC) is transformed in alternating current (AC). Station B is connected to station A and station A is connected to the national grid. In December 2018 this connection took place and and the production of solar energy started. Station A contains monitoring equipment.

Figure 14: Constructing the foundation

Figure 15: Placing the panels

Figure 16: Station A

Figure 17: Solar Highways noise barrier

Maintenance and cleaning

The contractor has maintained and cleaned Solar Highways for a period of 18 months, starting in December 2018 and ending in June 2020. Maintenance and cleaning will be reported on in Action C2 Monitoring energy performance and reliability, verifying techno financial model and overall evaluation report. In June 2020 the maintenance of Solar Highways is transferred to the Rijkswaterstaat projectteam ZN-A-Wegen. This team will take care of the maintaining, cleaning and inspecting the integrated noise barrier.

5.1.9 Action C1 Monitoring effects on air quality and noise levels

Responsible: RWS

The monitoring of effect on air quality and noise levels is carried out using the method calculating instead of measuring.

Air quality and noise levels

In October 2017 the Antea Group completed a report on the sound effects and a report on effects on air quality of Solar Highways. In the first part of the report is explained why noise levels are calculated. At the location of the Solar Highways along the A50 at Uden, there is a complex situation with highway noise, but also noise of activities by residents in the area behind the screen and noise from the nearby Volkel airport. It is almost impossible to reliably determine the effect of the sound barriers by means of measurements. Therefore, in this situation, it has been chosen to determine the acoustic effects of the Solar Highways by means of sound calculation. Results:

Noise levels	Noise-affected area in m2		
	No barrier	With Solar Highways	Effect
<50 dB	1.328.159	1.403.200	+ 75.041
50-55 dB	234.259	196.374	- 37.885
55-60 dB	80.665	57.200	- 23.465
60-65 dB	38.756	28.185	- 10.571
>65 dB	73.386	70.265	- 3.121

The effects on air quality are also calculated. It is difficult to measure the specific effect of Solar Highways because there are more changes in the situation than placing the barrier. The effects on the air quality is calculated for 18 locations, just behind the barrier. Comparing the situation without the barrier with the situation with a barrier, we see a reduction of the NO2 concentrations varying from 0,01 to 0,15 µg/m3 (year average), of the PM10 concentrations from 0,00 to 0,15 µg/m3 (year average) and of the PM2,5 concentration from 0,00 to 0,07 µg/m3 (year average).

The monitoring of the social-psychological effects is reported in paragraph 5.2.2.
See also Annex 5.0

5.1.10 Action C2 Monitoring energy performance and reliability, verifying techno financial model and overall evaluation report

Responsible: TNO

After the noise barrier with integrated PV-modules was placed and the monitoring equipment was installed the monitoring by TNO of the energy yield and the operational performance started. This monitoring continued for 18 months, till the end of the project in June 2020. The yield measurements of the prototype developed by ECN are also part of the monitoring.
The aim of the monitoring is to analyse which operation and maintenance strategy (O&M) is financially most beneficial. The action consisted of systematic gathering and analysis of data regarding the kWh yield, the uptime-downtime and cost of potential repair issues and corrective actions. The electrical output is monitored, but also the costs for O&M will be recorded. To find an optimal balance between electrical output and O&M costs, the installation is split into two different parts: the regular part and the research part. The research part is split into 6 different sections. On every section a different cleaning interval is applied: annual cleaning on both sides, annual cleaning on non-roadside only, cleaning every 6 months, non-road-side only, and no cleaning.

The results of the monitoring are also used to validate the techno-financial model.

Results:
Solar Highways, currently holding the record of the world's largest bifacial solar noise barrier, resulted to be a successful example of PV integration in infrastructure. To answer to the many practical questions related to the actual performance and maintenance of such a system, the noise barrier was monitored since commissioning for a period of 18 months, going from the 1/01/2019 to 30/06/2020.
The net yearly energy yield for 2019 was found to be 202.8 MWh/year, corresponding to an AC specific yield of 816.8 kWh/kWp. This amount of clean electricity could be used to power around 68 typical Dutch households. The total energy output of the 18-month period amounts to 325,5 MWh, with an overall performance ratio of 74.5%.
Thanks to the vertical east-west orientation of the bifacial PV panels, the SH system was able to capture light and generate electricity since the early hours of the morning to the late hours of afternoon-evening. During a typical sunny day, the power profile follows a double-peak shape with a dip around solar noon, when only diffuse light reaches the two sides of the solar modules.
Analysis of the monitoring results showed that for more than one year the power electronics in the system were not-optimally functioning due to their inability to find and operate the modules at the global maximum power point in partial shading conditions. The problem was solved thanks to a firmware update from the manufacturer; after fixing the power optimizers, yield and performance increased around 7%. With simulations, it was estimated that in 2019 the system suffered a loss of 3% to 5% because of this problem.
Furthermore, we investigated the effect of soiling and dust accumulation on the SH modules and the impact of cleaning. For the investigation, 5 different test areas were cleaned with different cleaning schedules, e.g. by varying frequency and/or the side that was cleaned. One test area was left uncleaned for the whole period, to be able to compare to an uncleaned situation. It was found that none of the cleaning events showed a measurable positive effect on the performance of the PV system. Therefore, it can be concluded the SH is not heavily affected by soiling and particles accumulation, most likely because of the almost-vertical tilt

of the structure which may facilitate the self-cleaning due to rainfall. Based on these findings, cleaning procedures are not considered necessary for the Solar Highways noise barrier for the purpose of increased energy output.
During the monitoring period, a few events of vandalism occurred, such as graffiti and module damages probably caused by rock throwing. However, actions were promptly taken to restore the system and no impact on the yield was found.
The CAPEX for the Solar Highways solar noise barrier was much higher than foreseen. In all income scenarios this leads to higher O&M costs than income generated by using or selling the electricity. This leads to a negative Return in Investment and negative Net Present Value. With cost reductions for the components and efficiency improvements in the tendering and building process, costs may be able to go down to a level that will result in a positive net present value and return on investment.

See for the complete report Annex 5.1 (2 documents)

5.1.11 Action C3 Installing energy performance measurement system

Responsible: TNO

The Solar Highways bifacial noise barrier is and will be monitored for energy performance. The specifications for the energy performance system were part of the procurement documentation. The equipment was installed and initially tested by the contractor. Every solar laminate is connected to two SolarEdge power optimizers, enabling monitoring on module level through the SolarEdge monitoring portal. For accurate measurements, AC power meters were installed measuring the total net production (and consumption). Eight AC meters were installed in total: one for every 'experiment section' and two for the main parts of the system.

Measurement equipment

The type and accuracy of the different measurement sensors was defined in the procurement documents. The following equipment was installed:

- Eight Janitza UMG 604-UMG power meters were installed. One for every 'experiment section' and two for the main parts of the system.
- Three Kipp and Zonen SMP3 pyranometers were installed: one on the east side and one on the west side of the solar noise barrier, both in the same orientation as the barrier. The third one was installed horizontally on top of the noise barrier.
- SolarEdge provides module level power monitoring on their online portal: monitoring.solaredge.com.

Data flows

Five minutely data from the power meters and the pyranometers is recorded. At the end of every day, data for that day is transferred to a TNO server, where it is further processed.

Figure 18: A part of the solar noise barrier, including the cabinets containing a part of the inverters (station B). Above the cabinets we see the east-facing pyranometer Solar Highways sound barrier

5.2. Dissemination actions

5.2.1 Objectives

An important goal of Solar Highways is to communicate the benefits of a noise barrier with integrated PV modules and disseminate the knowledge gained. The objectives for communication and dissemination have been elaborated in the communication plan (action D1, responsible: RWS) and the core message was formulated:
Solar Highways is a project of Rijkswaterstaat (the executive body of the Dutch Ministry of Infrastructure and Water Management) aiming at the development of an innovative noise barrier, generating electricity and reducing noise levels. The prototype is a noise barrier of 400 meters long and five meters high that generates solar energy on two sides, using integrated bifacial solar panels. A sustainable solution that produces energy for approximately 40 households. The construction of the screen starts in 2018. After completion the monitoring will start and last up to 2020.

The communication objectives are elaborated per stakeholder:
Governmental organizations:
- aware of the objectives, backgrounds and progress of the project
- work together, share knowledge
- positive attitude towards the project

Sound and solar experts:
- aware of the objectives, backgrounds and progress of the project
- know where current information can be found and shared
- take pride in the project and being ambassadors to others
- cooperate, share knowledge and skills
- contribute to the external communication about the project

Market parties:
- a lot of interest in the project
- aware of the objectives, backgrounds and progress of the project
- share knowledge and skills
- know where current information can be found and shared

Ambassadors and supporters:
- aware of the objectives, backgrounds and progress of the project
- very positive towards the project
- network for the project
- contribute to the external communication

Interest Associations:
- aware of the objectives, backgrounds and progress of the project
- know the project contributes to the sustainability objectives of the national government and RWS
- positive attitude towards the project
- willing to convince their supporters to be positive towards the project

Residents and businesses:
- aware of the objectives, backgrounds and progress of the project
- know the project contributes to a better environment
- positive attitude towards the project
- know this is a trial, willing to participate in the project

Public and press:

- know the significance of the project, the prototype is placed and that the project contributes to the sustainability objectives of the national government and RWS
- aware of the unique characteristics of the sound screen, the scale size and the extent to which it distinguishes itself from similar systems
- positive attitude towards the project
- know it is a test and that the results of the monitoring are decisive for a possible follow-up

Other relevant projects and programs:

- aware of the objectives, backgrounds and progress of the project
- willing to use the Solar Highways message in their communication so projects can reinforce each other.

5.2.2 Dissemination: overview per activity

Communication and dissemination plan (RWS)	D1	Completed on 22 December 2014 for the location Dordrecht. The plan was updated in October 2017 for the location Uden. The planning of communication activities was updated on a regular base. The plan describes the objectives, message and per stakeholder the deployment of possible means of communication. The plan includes a communication calendar.
Website	D2	The website went live on 26 December 2014 and was visited well: 2015: 4659 sessies/ 4206 users 2016: 2609 sessies/ 2141 users 2017: 2279 sessies/ 1953 users 2018: 3100 sessies/ 2500 users 2019: 7104 sessies/ 2672 users 2020: 2637 sessies/ 1184 users (t/m 30 juni) The website has been kept up to date until the end of the project (June 2020) and will be kept available by RWS until 2025 June 30. In Annex 5.2 a summary is given of the website statistics
Notice board at building site (RWS)	D3	The notice board with regard to the implementation phase was placed in June 2018, the notice board for the testing phase in December 2018. Before starting the building activities the contractor placed a temporary notice board along the A50 (June 2018). At the end of the construction phase, the notice board was replaced by a notice board announcing the testing phase (December 2018). In addition to the notice board along the highway, a permanent information board was placed for people walking by. On all boards the LIFE+ logo is applied. Shields with the Life logo are attached to the barrier, every 100 m, on both sides.
Public and business participation meetings (RWS)	D4	In the Grant Agreement three participation meetings are planned. The first one was planned for beginning of 2017. This meeting was held earlier (18th of May, 2016) to consult the business community to gather information for the procurement strategy. The second and the third meeting were replaced by a number of meetings (8 in 2017-2019) with residents and representatives (communication and sustainability) of the local municipality. In these meetings information about the building activities was given and the

		opportunities to participate in the exploitation of the PV part of the noise barrier were discussed. In a few occasions external experts were involved.
Technical working groups (RWS)	D5	RWS (D. van der Graaf) presented the project on the 14th of September 2016 in the Working Group Noise van Eurocities. The objective was to present the project again after finalizing the construction and after completion of the project. In consultation with the chairman of the Working Group the decision is made to present the project only twice. The second presentation was held by D. van der Graaf on the 26th of March 2019 in Brighton. ECN presented a paper at EU PVSEC 28 September 2017, in Amsterdam (NL): J. Kester, M. Jansen, M. de Jong, D. van der Graaf, *Reference Design For a Highway Noise Barrier with Integrated Bifacial PV*, Proceedings 33rd EU PVSEC, 2017. SEAC provided a visual presentation at the EU PVSEC 28 September 2017, in Amsterdam (NL): Minne de Jong, Menno van den Donker, Wiep Folkerts, *Solar Noise Barrier Projects in the Netherlands*. See also Annex 5.3
International conference (RWS)	D6	The international conference was held on the 13th of November 2019, together with and as part of the yearly Sunday conference. The cooperation with the Sunday organization resulted in more participants and reduction of the costs. For the Solar Highways part of the conference special invitations were send to stakeholders, experts and the senders of the Letters of Intent at the start of the project. The proceedings can be found in Annex 5.4 (2 documents)
Brochure (SEAC)	D7	An 8-page factsheet (brochure) has been produced, based on the new pilot location at the A50 near Uden of which 2000 copies were printed and distributed among inhabitants in Uden and among interested parties in the solar energy and building sectors. The brochure describes the goals of the pilot, explains the technology involved, what the impact of the project is on the environment and how the project aims to involve the inhabitants of Uden.
Film (SEAC)	D7	Originally planned in July 2017 but postponed in order to be able to present pictures of the completed barrier. There is a 6 minute film and a shortened version. In April 2019 both are placed on Youtube and accessible through the website.

		English subtitles are available. The film contains footage of the building process as well as the PV laminate production process. Furthermore it contains interviews with different stakeholders.
Technical publications (SEAC)	D7	Action finished 7-2-2020. Three technical publications were written: • Kester et al. - EUPVSEC 2017 - Reference Design for a Highway Noise Barrier with Integrated Bifacial PV • de Jong et al. - EUPVSEC 2018 - Building the World's Largest Bifacial Solar Noise Barrier • de Jong et al. - EUPVSEC 2020 Abstract - Monitoring Solar Highways Performance and lessons learned from operating a bifacial solar noise barrier See Annex 5.5 (3 documents)
Layman's report	D7	The layman's report is based on the Final Report completed in July 2020 and widely distributed among interested parties. See Annex 5.6

Figure 19: Notice board along highway A50 during the construction phase

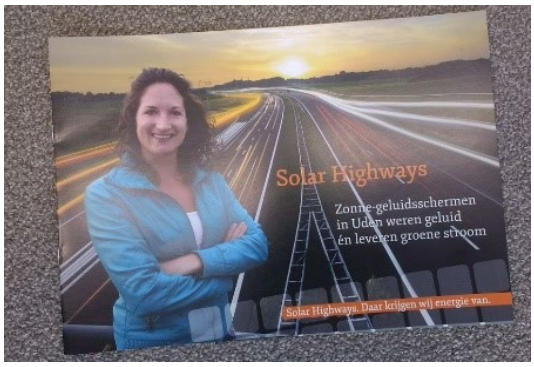


Figure 20: Front page of the Solar Highways brochure

Use of Life + logo

The Life + logo is attached to the prototypes for the PV module as made by ECN and also applied on the temporary notice boards, the noise barrier itself (every 100 meter) and the permanent information board. The logo is also used in all internally and externally held presentations, reports and on the project website.

Figure 21: The permanent information board in the municipal parc behind noise barrier Solar Highways

Communication and media
In October 2017 the press was informed about Solar Highways. Prior to that, the residents of Uden (about 400 addresses) received a letter with information about the project and the brochure. The purpose was to report the location, the objectives and the realization process of the Solar Highways project and, of course, to generate publicity. A large number of media have published an article based on the press message. Media were without exception positive.
Noise reduction and at the same time generating (solar) energy is mentioned well in the articles, as well was the EU LIFE + subsidy.
On a national scale, HP / DeTijd (magazine) and VARA (radio) have paid attention to the message. Also a lot of regional newspapers elsewhere in the country have brought the message, both on paper and online.
Tuesday, October 10 2017, we sent the press release on awarding the Solar Highways contract to Heijmans Wegen BV. The purpose was to announce that Heijmans will realize the project and to generate publicity for Solar Highways and RWS as a sustainable partner. This on the Day of Sustainability. A large number of media have taken over the message. On national and regional scale. The media and the reactions were positive. Incidentally there were reactions on social media, especially renewable / green inputs; also positive reactions. Roald Lapperre, our DG Environment and International at IenM, turned out to be a full-time ambassador to Twitter.
In March 2018 a press release was sent to give information about the progress of the project: site preparation, applying for permits and communication with nearby living people.
Next in June 2018 the media gave attention to the removal, transport and reuse of the existing concrete noise barriers within the A50 project. Of course the media were positive about this contribution to sustainability.
The last five milestones with positive media attention:

- September 2018, the mounting of the first bifacial solar panels
- December 2018, the construction and electrical installation is ready for operation and attached to the power grid
- February 2019, the Minister of Infrastructure and Watermanagement opens festively Solar Highways
- November 2019, Solar Highways international conference
- June 2020, the results of the 18 months of monitoring are announced

In Annex 5.7 a complete overview of media attention is given.

Feed-back responses from the local inhabitants
The social effects are difficult to investigate. Scientifical approved studies are time consuming and expensive. Moreover, results are often subject to discussion. In the Grant Agreement a survey in the surroundings was proposed. The project team has rejected this because of the uncertainty of the results and because it can be concluded on forehand that these will be unreliable. Instead an approach was chosen based on feed-back responses from the local inhabitants and analyses of the use of social media (with a distinction in positive, neutral or negative attention). The Commission has accepted this approach (Ref.Ares(2019)4477539-11/07/2019). The responses give an indication of the social effect of the integrated noise barrier.

Sentiment at the municipality of Uden was very positive from the start.
Local residents' sentiment was neutral to moderately positive.
Solar Highways was in line with the sustainability ambitions of the municipality and local residents were better protected against traffic noise by a 2-meter higher noise barrier that also generates green electricity. Ideally, this green electricity is used by local residents. That process to arrive at exploitation / ground lease has not yet been completed.

Nevertheless, it can be said that a development can be observed. A social impact, related to Solar Highways. And with a view to support and enthusiasm for solar energy, that effect, that development, can be labeled as positive.

It can be concluded that Solar Highways has generated enthusiasm and support for solar energy among local residents.
Residents of Uden in the West Area Platform and living in the Groenewoud district :
- have united
- have launched a newsletter
- have expressed their intention to set up an energy cooperative
- have 'adopted' the screen, as it were; by means of - a call for - social control an attempt is made to prevent possible damage to the screen by vandalism
- want to purchase the green electricity from Solar Highways
- want to look at other options for generating / purchasing green energy, when exploitation / ground lease Solar Highways is not possible

5.3 Evaluation of Project Implementation

In the beginning of the project the location near Dordrecht appeared to be not suitable and a search for a new location was carried out. This resulted in a serious delay which was communicated with the Commission. The planning was adapted and mainly by shortening the monitoring period, the end date was kept the same. The Commission agreed on the altered planning in July 2015.

Delays per action did occur, but did not result in a change of the end date of the project. Within the project the focus was strictly kept on December 2018: the date the integrated barriers should be operational. This milestone was achieved in time and finally Solar Highways was completed in time on the agreed end date of the 30th of June 2020. In the table below per action the completion date is given.

Task	Foreseen in proposal	Achieved	Evaluation
A1	Report with results on physical features of the location, the needed permits and consultation of the stakeholder.	24-01-2018	Achieved, including a motivation of an altering of location. The altering caused a serious delay. An adapted planning with no effect on the end date was proposed to the Commission and accepted.
A2	Final benchmark report.	01-01-2017	Achieved.
A3	Report on techno-financial model	20-04-2017	Achieved.
A4	Report with proposals for design of the integratable bifacialmodule and electrical system interconnect and proven results on quality and lifetime	02-04-2018	Achieved. ECN made two designs as well as two prototypes. One of these prototypes was especially made for the Innovation Expo and a meeting of EU ministers, 14 April 2016 in Amsterdam. The second prototype was placed at the ECN premises and used for outdoor monitoring since October 2017. The design of this prototype was used as a reference design in the procurement procedure. After the decision to integrate the reporting on the monitoring with Action C2, the final report on Action A4 could be completed.
A5	Report with procurement strategy, contract and functional specification with respect to PV technology. Including the evaluation and ranking of the offers.	16-11-2017	Achieved. All strategy and tender documents were available in time for the procurement. The offers of the contractors were evaluated and the contract has been assigned. The report about this action was completed in November 2017.
A6	Report on requirements for connection to the	17-03-2016	Achieved.

	electricity grid and energy performance model.		
B1	Implementation: PV noise barrier with bi-facial PV's	06-12-2018	Achieved. The start of the energy production is one of the most important milestones and this was reached in time: two week before the date in the planning sent to the Commission in June 2015. The contract has been signed in October 2017 and the integrated noise barrier went operational on the 6th of December 2018. Solar Highways was opened on the 18th of February 2019. The barrier is maintained and cleaned by the contractor until June 2020, the end of the project. The report on the maintenance and cleaning is part of Action C2.
C1	Reports on the effects on air quality and noise levels	26-10-2017	Achieved. Effect on air quality and noise levels were calculated by Antea. The Commission accepted to limit the social study to the different feed-back responses from the local inhabitants as proposed. This study is carried out as part of Action D4. Annex 5.0
C2	Evaluation report including monitoring measurements, energy performance, verified techno- financial model, socio-economic assessment, conclusions and recommendations.	13-08-2020	Achieved. The monitoring results were analyzed every three months. After a year of monitoring, the results were summarized in a report. Two other reports are added to this action: a report on monitoring the prototype (part of action A4) and a report on cleaning and maintenance (part of action B1).
C3	Installed monitoring equipment	06-12-2018	Achieved. The type and accuracy of the different measurement sensors was defined in the procurement documents. Eight Janitza UMG 604-UMG power meters and three Kipp and Zonen SMP3 pyranometers were installed. SolarEdge provides module level power monitoring on their online portal: monitoring.solaredge.com.
D1	A report with the communication and dissemination plan.	22-12-2014	Achieved. Initial report was completed in December 2014. Update was carried out after location change.
D2	Website	2014-2025	www.solarhighways.eu went operational in 2014 and will be kept available until July 2025 according article 13.7 of the Common Provisions.
D3	Notice boards at building site	04-06-2018	Achieved. After the construction phase the notice board was adapted for the testing phase.
D4	Report with summary of all		Partly achieved. The first meeting was held on the 18th of May 2016) to

	public and business participation meetings (including meeting minutes, list of participant and workshop materials)		consult the business community to gather information for the procurement strategy. This meeting is documented. The originally planned two other meeting were replaced by a number of meetings (8 in 2017-2019) with residents and representatives of the local municipality. These informal meetings are not documented.
D5	Report on external technical working group meetings	14-09-2016 28-09-2017 26-03-2019	Achieved. The project has been presented twice in the Working group Noise Eurocities and on the and EU PVSEC congress.
D6	Proceedings of international conference	13-11-2019	Achieved. The conference was held on the 13th of November 2019. Proceedings are available on www.sundaynl.nl.
D7	Brochure Solar Highways	3-10-2016	Achieved and available on www.solarhighways.eu.
D7	Film	04-04-2019	Achieved and on Youtube. • https://www.youtube.com/watch?v=3qgAhtDsz4U • https://www.youtube.com/watch?v=YEhADKRiwMo
D7	Technical publications	07-02-2020	Achieved. Three technical publications were written: • Kester et al. - EUPVSEC 2017 - Reference Design for a Highway Noise Barrier with Integrated Bifacial PV • de Jong et al. - EUPVSEC 2018 - Building the World's Largest Bifacial Solar Noise Barrier • de Jong et al. - EUPVSEC 2020 Abstract - Monitoring Solar Highways Performance and lessons learned from operating a bifacial solar noise barrier
D7	Layman's report	June 2020	Achieved. A layman report was written based on the monitoring report (C2).
E1	Overall projectmanagement	Oktober 2020	Achieved. Project completed with sending Final report tot European Commission. The Inception Report, Progress Reports and Mid Term report were sent according the planning to the Commission.
E2	Partnergroup meetings and steering group meetings		Achieved. During the process a number of partner group and steering group meetings were held to control the project.
E3	Networking with other projects		Achieved. Other solar projects were visited and other projectteams visited Solar Highways. The website was available for all

			interested parties and supplied news and information.
E4	After LIFE communication plan		Achieved. Experiences and knowledge are widespread and available.
E5	Audit report	29-10-2020	Achieved see annex 6.7

Overall project management (Action E1)

The project management consisted of a Partner Group and a Steering Committee in which all beneficiaries were represented. In a Partnership Agreement the organisation, responsibilities and other appointments between the partners were elaborated. The Partner Group and Steering Committee met on regular basis and discussed the progress of the project and the reporting to the Commission.
In the start of the project the originally foreseen location near Dordrecht appeared to be not suitable and another location had to be found. The project overcame this setback with success. The Commission agreed with the solution, the new location near Uden and the adapted planning. The end date was kept the same, the monitoring period was shortened to 1,5 year. From here on the project made good progress and all deliverables were realized without serious problems. All required reports were submitted and accepted in time. The monitor appointed by the Commission visited the project every year and advised about the financial and administrative aspects. Questions were also adequately answered by mail. During the project, the end date was never adapted.

In 2018 it was necessary to ask the European Commission to amend the Grant Agreement because of a partner change and because of an increase of the costs. Especially the realization appeared to be more expensive: the contractor offered the realization for € 3,0 million, significantly above the estimate in de Grant Agreement of € 2,3 million. Above that the personnel costs exceeded the estimations in de Grant Agreement. Especially the personnel cost for the overall management and the supervision of the implementation were underestimated, partly due to the innovative character of the project.
With regard to the partners, an amendment was necessary because the partner ECN became part of TNO.
The amendment was accepted by the European Commission and the Partnership Agreement was adapted to the altered situation.

After completion of the solar barrier in November 2018 the contractor was kept responsible for maintenance and cleaning until the end of the project in June 2020. This period of 18 months was used for monitoring purposes. In June 2020 the maintenance and cleaning became the responsibility of the standing organization of Rijkswaterstaat. A separate contract was produced and put out to tender.

During the process special attention was paid to the exploitation of the solar installation. One of the objectives is to show the financial benefits and the social impact. To realize both objectives a lot of effort has been paid to lease the installation to a cooperation of residents living behind the barrier. Such a lease results in the best business case and also contributes to the relation with the neighborhood. This is important to reduce the risk of vandalism and graffiti. To organize the lease appeared to be very difficult: decision-making within RWS, establishing an energy cooperation of residents and reaching an agreement with this energy cooperation about the exploitation. Rijkswaterstaat wants to keep sufficient control over the barrier to fulfil its responsibilities as a road authority and Solar Highways does not fit in the

regulations of Ministry of Finance. This Ministry is important because they are the official owner of state assets and they decide about the lease.
The efforts and meetings within Rijkswaterstaat and with the Ministry of Finance (owner of the state property and responsible for taxes) resulted in a lot of experience, but unfortunately not yet in a ground lease contract that could be tendered. The produced electricity goes in the national grid and is taken into reduction from the overall electricity consumed by Rijkswaterstaat. Note that all proceeds of the produced electricity are used to pay back a kind of mortgage within Rijkswaterstaat. The mortgage (€ 400.000) was used in the co-financing of the project as money was given from the "duurzaamheidsversneller", a specific budget Rijkswaterstaat uses to make possible sustainability projects. Moreover the proceeds from produced electricity will never exceed the costs of maintenance (estimated € 20.000/year). The efforts to involve the residents and to realize a better business case will continue after the end of the project. An important restriction remains that the Commission does not allow commercial use of the barrier within the first five years after the project.

In July 2018 the cooperation between the partners and within the organization of Rijkswaterstaat was evaluated. Experiences were shared with regard to the collaboration between the partners and the way Rijkswaterstaat handles technical and social innovations.

After the completion of the project and the last payment an audit was carried out.

Networking with other projects (Action E3)
Networking with other projects is sharing knowledge. Solar Highways networked in organized meetings, congresses and a lot of occasional contacts. These contacts are all different, but they all have in common the need to share information. Solar Highways has generated a lot of publicity and stimulated further developed knowledge. After the end of the project, request for information will be directed to the right persons/ platforms.

Solar Highways and RWS NOVA
RWS NOVA provides expertise in the field of exploitation and has had a large share in the preparation of the business case and exploitation models fort Solar Highways. A novum within RWS is the objective to involve residents in the exploitation of the installation. The way this could be done is interesting within and outside Rijkswaterstaat. Solar Highways has been regularly approached by municipalities, residents and businesses with the specific information requests on the co-use of noise barriers. Knowledge about this has been developed within the project together with RWS NOVA and the Rijks Vastgoed Bedrijf. This knowledge is developed by RWS NOVA and will be developed further.

Solar Highways and RWS Energy coordinators
Rijkswaterstaat created the function of energy coordinators in 2019. Each region of Rijkswaterstaat has such an official who is specifically concerned with energy issues. There is coordination on the policy and communication. Between the coordinators, but also with the top managers within Rijkswaterstaat. Rijkswaterstaat is still in the process of exploring how to deal with solar noise barriers and how to deal with third-party initiatives.
In 2019, Solar Highways agreed that requests for information on the use of noise barriers owned by Rijkswaterstaat to generate solar energy, will be referred to the energy coordinators. In this way, uniformity and continuity in communication are guaranteed. The knowledge of these coordinators is also maintained via RWS NOVA.

Solar Highways and the management of the Ministry
Solar Highways has been discussed in the board of Rijkswaterstaat. The discussion concerned mainly the exploitation. Solar Highways was also in the spotlights during the presentation of the Sustainability Report to the Secretary-General of the Ministry. The project manager and the alderman of Uden took part in the table conversation with the Secretary-General. The minister herself has also been regularly informed about Solar Highways. She carried out the opening of the project in February 2019. In October 2019, the potential of solar noise barriers was discussed with the Director-General of Rijkswaterstaat. It has been decided to wait with decision making and to determine first an strategy concerning the use of the assets of Rijkswaterstaat for solar applications and wind turbines.

See also Annex 5.8 .

After LIFE communication plan (Action E4)
The project Solar Highways has ended on the 30th of June 2020. During the project there have been many contacts with other projects and organizations. A lot of attention has been paid to the communication and the dissemination of knowledge. The international congress in November 2019 has been visited well. The website contains a lot of information and will be available at least until the 30th of June 2025. In case more information is wanted, it is easy to contact Rijkswaterstaat through the website. As a result Solar Highways is well known and the knowledge is wide spread.
During the process, special attention has been paid to secure the information. In an evaluation lessons learned were determined, especially about the process. Each department of Rijkswaterstaat has an energy coordinator. These coordinators are informed about Solar Highways and they coordinate the information to internal and external interested parties.

In the Grant Agreement (2014) an important role for the after Life communication was foreseen for the Eurocities Working Group Noise, Forever Open Roads and the Programme for measures for Air and Noise of Rijkswaterstaat. The working group and Forever Open Roads signed a Letter of Intent and received an special invitation for the Solar Highway congress. The project was twice presented in a meeting of the working group. The RWS-programme is now only focussed on noise. The management of this programme is well informed and has also visited the project site. ProRail, the organization responsible for the railroads in the Netherlands, has a similar program as RWS. ProRail has also visited the building site several times. All information of Solar Highways is available for ProRail.

The communication about Solar highways and the dissemination of knowledge will continue in- and extern the partners using the existing structures of their organizations. No special arrangements are made. The way the communication will continue depends strongly on the ambition and possibilities of the organization. The Solar Highways team has supplied all necessary information.

See also Annex 5.9 After Life Communication Plan.

Outcome indicators
See Annex 5.10.

5.4 Analysis of long-term benefits

5.4.1 Environmental benefits

All sources of renewable energy make use land area. In the transition toward a fully renewable energy supply, a competition for land area is arising. Dual use of area is of key importance to minimize the effect of this competition for land on the conservation of valuable nature or other use. In the urban environment solar energy is very suitable to be integrated in existing and new buildings and infrastructure[4]. In the Solar Highways project, solar electricity generating elements are used as integrated elements in a noise barrier.
The Solar Highways photovoltaic noise barrier will produce renewable energy. The yearly amount of generated electricity is estimated between 190 and 215 MWh by the contractor and partner TNO. This is equivalent to the electricity consumption of 63 to 72 typical Dutch households. The associated yearly avoided CO_2 emission is estimated between 90 and 102 ton[5]. Over the estimated lifetime of 30 years, the total generated electricity is estimated between 5.3 and 6.0 GWh and the avoided CO_2 emission is estimated between 2520 and 2850 ton.

The primary function of the noise barrier is to protect people from noise. In the case of Solar Highways, the noise barrier is placed adjacent a road next to a residential zone. In this way the inhabitants are protected from excessive noise levels. Demonstration of both functions combined will simultaneously accelerate the use of PV and noise barriers along Europe's highways, greatly contributing to achieve the EU objectives concerning climate change, noise and air.

5.4.2 Long term sustainability

The transport sector is a large contributor to the emission of greenhouse gasses. At the same time, the infrastructure used for transportation uses a large fraction of land area. In the Netherlands, infrastructure uses 1200 km^1 of land area (3% of total area). By initiating this project we show the feasibility of integrating renewable energy sources into the infrastructure. By setting up this project not as a one-time pilot, but through a tendering procedure for a permanent fixture, the procurement of the installation can be copied for future projects. In this way, future projects will be much easier to set up and implement and set an example for innovative tendering in infrastructure building projects.
Integrating renewable energy sources into infrastructure will open up new economic opportunities for infrastructure building companies, as well as their subcontractors. This will result in more employment in the renewable energy and infrastructure sectors. Most economic activity related to solar energy material manufacturing is now located in Asia. Integrating solar energy generating elements into infrastructure requires knowledge of the local legislation and infrastructure, and therefore opens up opportunities for local or European businesses to develop and produce these materials.

[4]W. Folkerts et al., Roadmap PV Systemen en Toepassingen, https://www.seac.cc/wp-content/uploads/2018/04/Roadmap-PV-Systemen-en-Toepassingen-FINAL.pdf
[5] Calculation based on the numbers from https://www.co2emissiefactoren.nl/lijst-emissiefactoren/

5.4.3 Replicability, demonstration, transferability, cooperation

Full integration of solar modules will result in a price reduction of solar energy integrated in the infrastructure, compared to solar energy systems added to infrastructure elements. This price reduction is realized by saving on material costs by the dual function of the materials. In the case of solar noise barriers these materials are: the glass, which is used for blocking of noise and as an encapsulant for the solar cells, the mounting structure, used for the noise barrier and the solar installation. Furthermore the mounting structure is used for guiding of the cables. This price reduction will open possibilities for further commercialization and scaling up. Costs can be saved on labour because the noise barrier and PV elements are installed in the same instance.

The energy produced by noise barriers with solar panels can generate financial benefits. There are several possibilities to realize this. First of all, the installation can be directly connected to an end user, for instance to an industry or the lightning of motorways . This generates direct profit to the industry or highway authority involved. Another possibility is a connection to the (inter)national electricity grid and an agreement with the electricity provider . Usually the provider will reimburse the market price of the produced energy. There are however possibilities to gain more financial profit. On one hand there are subsidies from the local or national government to stimulate the production of green energy. On the other hand, energy providers might be interested to pay more than the market price in order to improve their image or create possibilities to ask a higher price for this kind of electricity. For Solar Highways the most profitable way of exploitation is to rent the installation to a local energy corporation. These local energy corporations can make use of a tax advantage granted by the national government and are able to pay the highest rent. An important condition for this tax advantage is that the members of the corporation should live nearby the installation. In Solar Highways this kind of exploitation will be tested. Apart from the financial benefits, Solar Highways expect a greater involvement of the community nearby resulting in less resistance to noise barriers and less vandalism.
If this test does not succeed, the generated energy will be used to reduce the electricity costs of Rijkswaterstaat.

There is public opposition against using public space for renewable energy production. This is most present for building wind turbines on land, but also large solar parks start to attract opposition. Therefor it is crucial to use the available space for multiple purposes. The Solar Highways project aims to show the feasibility of such dual space utilization.

The location of the installation ensures high visibility of the project. The installation is built along the A50 highway in Uden, with more than 20 Million vehicles passing by yearly[6]. In this way the Solar Highways project acts as an example and showcase project for integrating solar energy in the infrastructure.

Possible replication is to be expected in projects such as a municipal road in Alkmaar, a regional road N279, highway A37 in the province Drente, highway A58 Eindhovene-Tilburg and an national project of railroad manager ProRail.

[6] Numbers from Statistics Netherlands: http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=82855ned

5.4.4 Innovation and demonstration value

Solar Highways is an innovative project that aims to show the technical feasibility and the environmental, social and financial benefits of using multifunctional constructive elements for building highways noise barriers, in which a bifacial PV solution has been integrated. Innovations are:

<u>The use of bifacial solar cells in a solar noise barrier along a highway running north-south</u>
The advantage of *bifacial* solar noise barriers is that they can be used alongside any road, regardless of its direction[7]. At the Solar Highways location, the road runs north-south. Therefore the noise barrier sides will face east and west. Using conventional monofacial solar cells would mean a suboptimal electricity output. By using bifacial cells, the output will be increased by capturing light in the morning from the east side, and capturing light in the afternoon using the other side of the barrier.

<u>Full integration of solar modules, electronics and cables into the noise barrier</u>
Earlier solar noise barrier projects suffered significantly from vandalism and theft. In our project, the PV elements are fully integrated into the noise barrier. Using material common to noise barriers, they are designed to be resistant to vandalism. Also the full integration will protect them from theft.

<u>Implementing a Most Economically Advantageous Tender' (MEAT)</u>
In infrastructure building projects, competition is based merely on price. In the project we set up a MEAT tendering procedure, enabling the weighing of monetary alongside non-monetary aspects in the same procurement. In this type of procurement, value is added to aspects other than cost price. In the case of the Uden solar noise barrier procurement, the MEAT tender aimed to optimize the system, together with measures to minimize the efforts and cost for maintenance. Participants in the procurement were challenged to improve upon a reference design by ECN.

<u>Monitoring of energy production in relation to maintenance</u>
After commissioning of the solar noise barrier, SEAC will carefully monitor the total solar energy output of the installation for 18 months. We will not only monitor the total energy output of the bifacial solar noise barrier, also the efforts and costs needed for maintenance will be assessed. To find out what is the optimal cleaning frequency with the business case in mind, a part is split into 5 identical experimental sections. Each section will have a different cleaning regime. By assessing differences in energy output and relating them to the cost of cleaning, we can design the optimal maintenance scheme with the business case in mind.

5.4.5 Long term indicators of the project success

Long term indicators of the project success are:
The continuing renewable energy production and avoided CO_2 emissions
The initiation of follow-up projects in Europe, learning from the technical and organizational innovations.

[7] G.J.Faturrochman et al., Maximizing annual yield of bifacial photovoltaic noise barriers, Solar Energy, 2018

6. Annexes

	Inception Report	1st Progress Report	Mid Term Report	2nd Progress Report	Final Report	
Partnership Agreement						
1st Agreement	Annex 1.1					
2nd Agreement						Separaat verzonden op 13-09-2019 (post en email)
Administrative part						
Action E1			Annex 4.1			Planning
Deliverables						
Action A1	Annex 2.6					Afweging geluidmaatregelen locatie Dordrecht
Action A1	Annex 2.7					Location selection plan
Action A1			Annex 5.1			Eindrapportage Action A1
Action A2	Annex 2.8					Benchmark study
Action A3		Annex 1.2				Techno-financial model
Action A3			Annex 5.2			Eindrapportage Action A3
Action A4		Annex 1.3				Design PV integration
Action A4			Annex 5.3			Eindrapportage Action A4
Action A4				Annex 3.1		Eindrapportage Action A4
Action A5			Annex 5.4			Eindrapportage Action A5
Action A6	Annex 2.9					Offer SPSS
Action A6		Annex 1.4				SPPS requirements report
Action A6			Annex 5.5			Eindrapportage Action A6
Action B1				Annex 3.2		Eindrapportage Action B1
Action E1	Annex 2.4					Revised schedule
Action E1	Annex 2.5					Format time sheet
Action E2	Annex 2.1					Minutes PMT meetings
Action E2	Annex 2.2					Minutes steering group meetings
Action E3	Annex 2.3					Overview of networking activities
Action C1			Annex 5.6			Rapportage Geluid, Antea
Action C1			Annex 5.7			Rapportage Lucht, Antea
Action C1					Annex 5.0	Social study (Maurice)
Action C2					Annex 5.1	Eindrapportage Action C2
Action C3				Annex 3.3		Eindrapportage Action C3
Action D1	Annex 2.10					Communication plan
Action D1			Annex 5.8			Communicatie plan (update 2017)
Action D1			Annex 5.9			Communicatie agenda
Action D2			Annex 5.10			Statistieken website
Action D2				Annex 3.4		Statistieken website
Action D2					Annex 5.2	Statistieken website
Action D3				Annex 3.5		Eindrapportage Action D3
Action D4				Annex 3.6		Tussenrapportage Action D4
Action D5					Annex 5.3	Rapportage Technical Working Groups
Action D6					Annex 5.4	Proceedings International Conference
Action D7			Annex 5.11			Brochure
Action D7			Annex 5.12			ECN paper EU PVSEC
Action D7			Annex 5.13			Overzicht media aandacht
Action D7				Annex 3.7		Overzicht media aandacht
Action D7					Annex 5.5	Technical publications
Action D7					Annex 5.6	Laymen's report
Action D7					Annex 5.7	Overzicht media aandacht
Action E3				Annex 3.8		Tussenrapportage netwerkactiviteiten
Action E3					Annex 5.8	Rapportage netwerkactiviteiten
Action E4					Annex 5.9	After Life Communication Plan

Project output indicators						
	Annex 4.1					Environmental policy and governance
	Annex 4.2					Information and communication
	Annex 4.3					Awareness raising
					Annex 5.10	Output Indicators, final tables
Financial part						
				Annex 1.1	Annex 1.1	Answers to questions of the EU
		Annex 1.1				Timesheet examples
			Annex 6.1			Time registration and procedures ECN
	Annex 5.1					Declaration non-recoverability VAT-SEAC
	Annex 5.1					SEAC Contract external assistance 2014-2015
			Annex 6.2			Declaration non-recoverability VAT-RWS
			Annex 6.3			Consolidated Cost Statement for the project
			Annex 6.4			Financial Statement RWS
			Annex 6.5			Financial Statement ECN
			Annex.6.6			Financial Statement SEAC
					Annex 6.1	Standard Payment Request and Beneficiary's Certificate
					Annex 6.2	Consolidated Cost Statement for the Project
					Annex 6.3	Financial Statement RWS
					Annex 6.4	Financial Statement TNO
					Annex 6.5	Financial Statement ECN
					Annex 6.6	Financial Statement SEAC
					Annex 6.7	Auditor's report