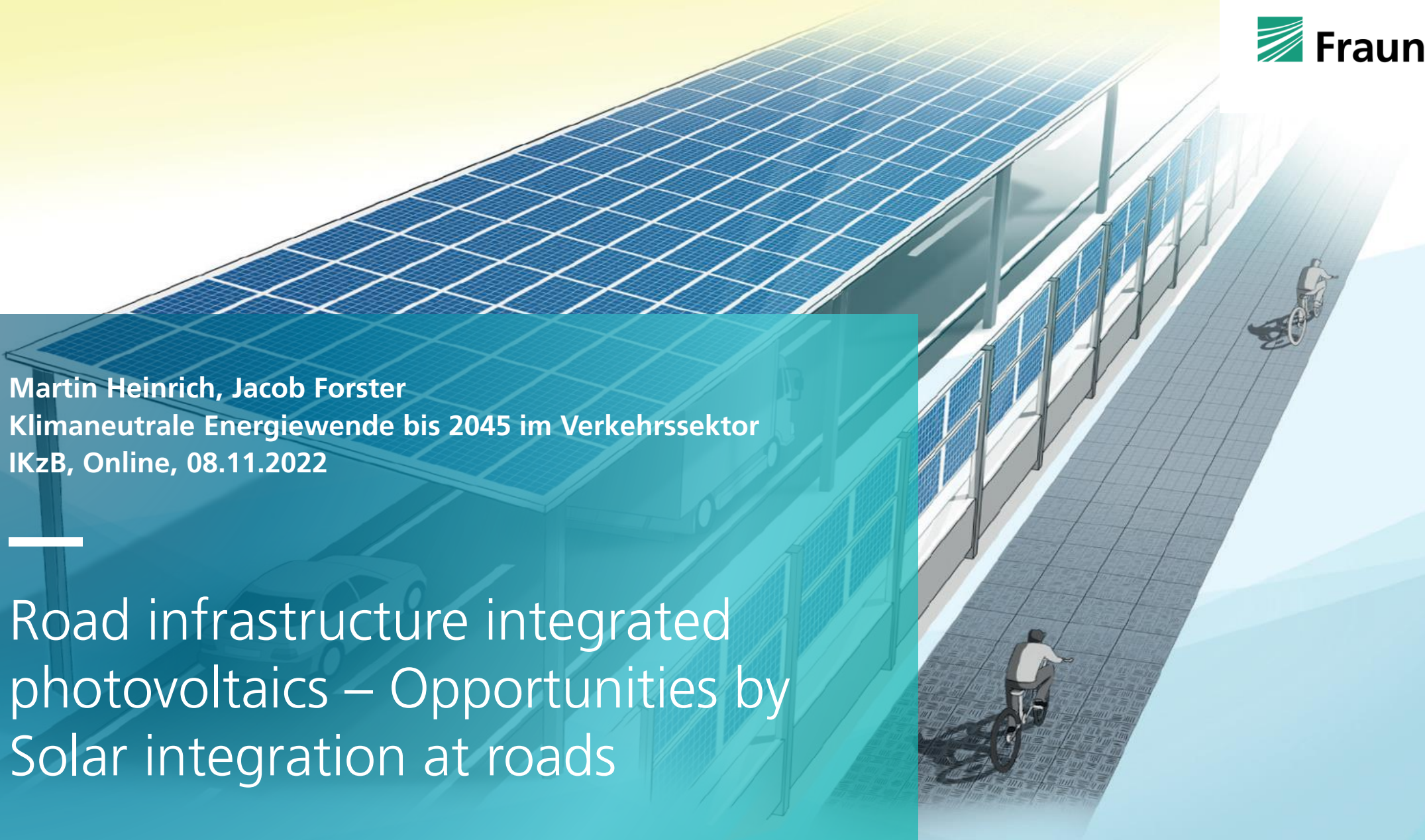


Martin Heinrich, Jacob Forster
Klimaneutrale Energiewende bis 2045 im Verkehrssektor
IKzB, Online, 08.11.2022

Road infrastructure integrated photovoltaics – Opportunities by Solar integration at roads



Fraunhofer ISE

At A Glance

Directors:

Prof. Dr. Hans-Martin Henning
Prof. Dr. Andreas Bett

Staff: ca. 1400

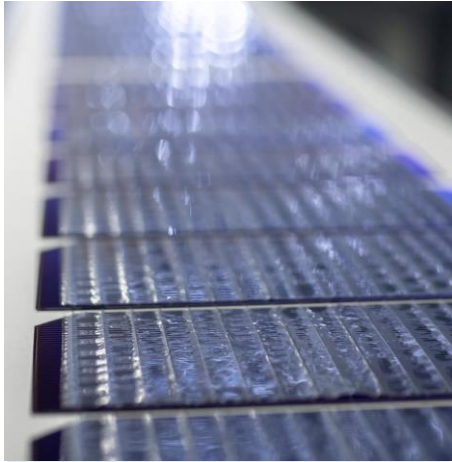
Budget 2022: €105,8 million

Established: 1981



Fraunhofer ISE

At A Glance



Photovoltaics



**Energy Efficient
Buildings**



**Solar Thermal Power
Plants and Industrial
Processes**



**Hydrogen
Technologies and
Electrical Energy
Storage**



**Power Electronics,
Grids and Smart
Systems**

Fraunhofer ISE

Scope of Our Work

Research

- Materials
- New devices
- Proof-of-Principle
- Simulation and modeling
- Methods

Development

- Equipment
- Process technology
- Transfer to industrial scale
- Proof-of-concept

Implementation

- System design
- Monitoring
- Demonstration
- Testing and certification
- Quality assurance

Integrated Photovoltaic Overview

Possibilities to integrate PV

- Building Integrated PV (BIPV)
- Agri-PV (APV)
- Floating PV (FPV)
- Vehicle Integrated PV (VIPV)
- Urban Photovoltaic (UPV)
- **Road Integrated PV (RIPV)**



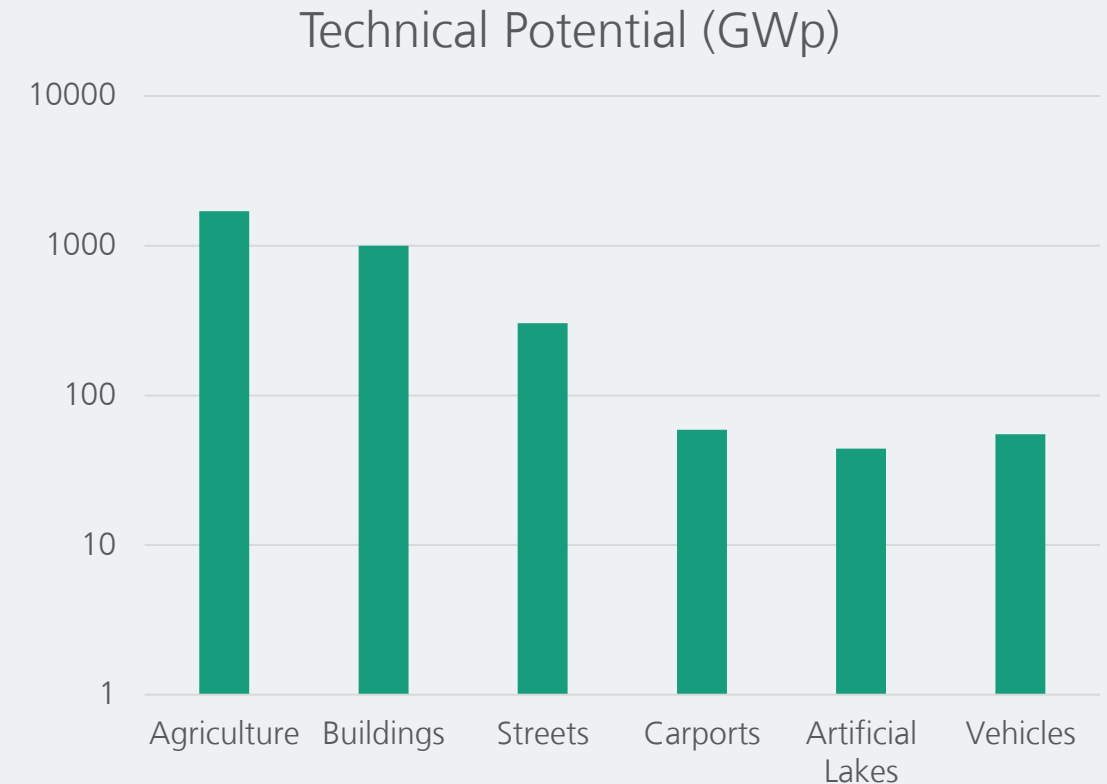
Technical Potential for Integrated PV

Estimated technical potential for integrated PV in Germany about 3.160 GWp [1]

Integrated PV opens many opportunities

- Avoiding conflicts about land use
- Reduction of material use
- Local energy production
- Local production of PV-components

[1] Wirth *et al.*, Potenziale der Integrierten Photovoltaik in Deutschland, 36. PV Symposium, Mai 2021.



Integrated Photovoltaic

Road Integrated Photovoltaic

- Roads and Rails: 3.300 km² in total (5% of land area)

Federal highways	289 km ²
Federal roads	343 km ²
Rural roads	421 km ²
Regional roads	409 km ²
Inner city roads	1720 km ²
Railways	115 km ²



Federal highways in Germany © Wikimedia

https://de.wikipedia.org/w/index.php?title=Datei:Autobahnen_in_Deutschland.svg#filelinks

Integrated PV

High Potential for RIPV

Estimation of technical potential based on current findings [1]

- Inner-city areas not considered here (shading).
- For street roofing, a high performance ratio is assumed (85 %)

Integration Type	Technical Potential		
Street Roofing	1285 km ²	257 GWp	238 TWh/a
Street Integration	172 km ²	34 GWp	14 TWh/a
Rail Bed Integration	50 km ²	10 GWp	6 TWh/a
Noise Barriers	14 km ²	3 GWp	2 TWh/a

Note

The economic-practical potential depends on general and site-specific factors.

[1] Wirth *et al.*, Potenziale der Integrierten Photovoltaik in Deutschland, 36. PV Symposium, Mai 2021.

Integrated Photovoltaic

Road Integrated Photovoltaic

Possibilities to integrate PV

- Next to the road:
 - As a path border and for noise protection → **Project PVwins**
- Above various surfaces:
 - As roofing → **Project PV Süd**
- In the traffic area:
 - Walkable and drivable road surface, in verges or track beds



RIPV Implementation Options

PV integration *next* to the road

Potentials

- No additional construction necessary for the PV components
- Very low land consumption
- Close proximity to potential consumers e.g. EV charging stations
- Paying off cost of infrastructure over time

Challenges

- Non-ideal alignment depending on structure function (especially vertical boundaries and noise barriers)
- Risk of vandalism and safety in case of accidents
- Noise control functions or impact protection not compatible with conventional PV module concepts



PVwins

PV integration *next* to the road

Project timeframe: 01.04.20 – 31.03.23

Joining different competences

Fraunhofer ISE:

Project lead, Integrated PV and new solar products

R. Kohlhauser GmbH:

Innovative noise barrier concepts

Igrapower GmbH:

PV system planning and operation

Megasol:

Individual PV-module production



Project partners



Advising institutions



RIPV Implementation Options

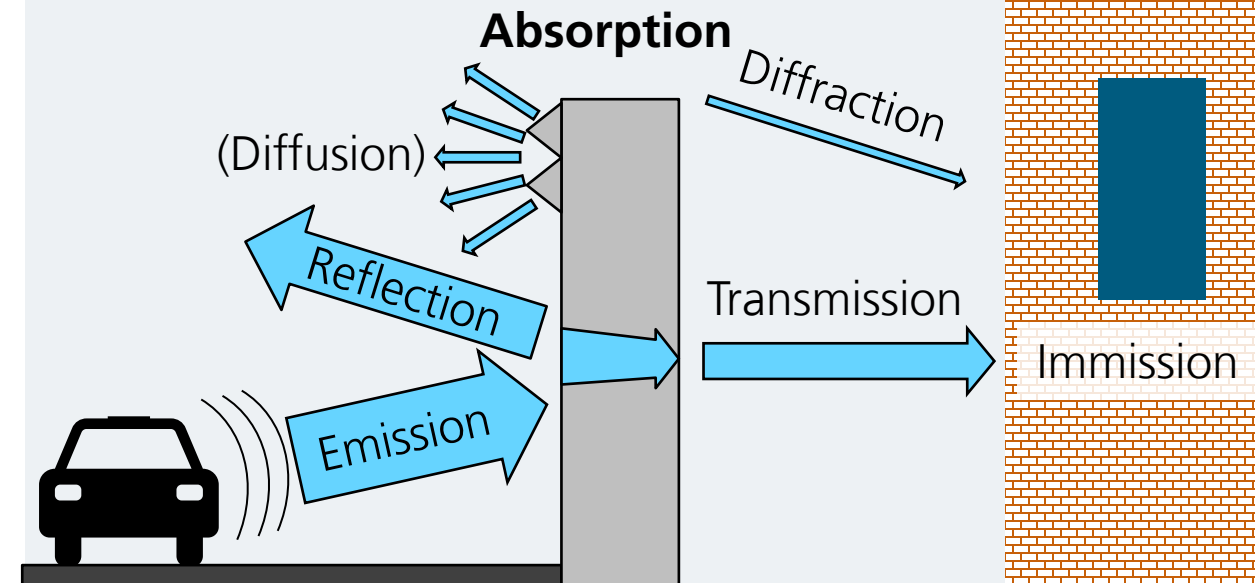
PV Noise Barriers

Acoustic properties of noise barriers

Absorption Requirement Levels according to ZTV LSW 2.2/ DIN EN 1793-1		
Group	Schallabsorption DLa [dB]	Description
A1	< 4	not absorbing, reflecting
A2	4 - 7	absorbing
A3	8 - 11	highly absorbing
A4	> 11	

Absorption:
Ability to absorb
sound energy

Noise Insulation:
Emission – Immission
> 24 dB(A)



RIPV Implementation Options

PV Noise Barriers

Acoustic properties of noise barriers

Absorption Requirement Levels according to ZTV LSW 2.2/ DIN EN 1793-1		
Group	Schallabsorption DLa [dB]	Description
A1	< 4	not absorbing, reflecting
A2	4 - 7	absorbing
A3	8 - 11	highly absorbing
A4	> 11	

- Good example for Integrated Photovoltaic: Incorporating both acoustic functions of absorption and noise insulation and PV power production

Group A1:
Sound reflecting PV
elements on large
area



Group A2:
Fractional use of PV
modules combined
with acoustic
absorber elements



Group A3:
Sound absorber
elements on large
area, PV only as top
mount



RIPV Implementation Options

PV integration *above* the traffic area: Roofing

Potentials

- Weather protection for traffic areas and road users
- Additional requirements primarily for substructure (integration of high-quality glass-glass PV modules)
- Sound insulation functions when combined with side walls
- Very large surface potentials due to roads, cycle paths, footpaths and parking areas
- Solar yield almost independent of road layout, bifacial modules and high performance ratio through rear ventilation

Challenges

- Need for the most cost-effective and durable substructure possible
- Dynamic loads from underlying traffic and wind and static loads from snow
- Safety of overhead installation and fall protection of PV modules



PV Süd

PV integration *above* the traffic area

Project timeframe: 03/2020 - 02/2023

Austrian Institute of Technology GmbH (AIT):

Project lead, Effect on street, concept for supporting structure

Fraunhofer ISE:

PV-module technology development and optimization, tests and prototypes

Forster Industrietechnik GmbH:

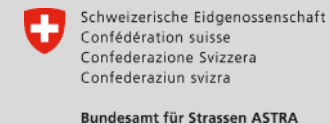
Support in concept development, demonstrator implementation, requirements



Project partners

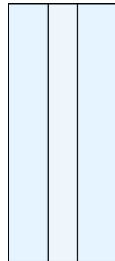


Advising institutions



PV Süd

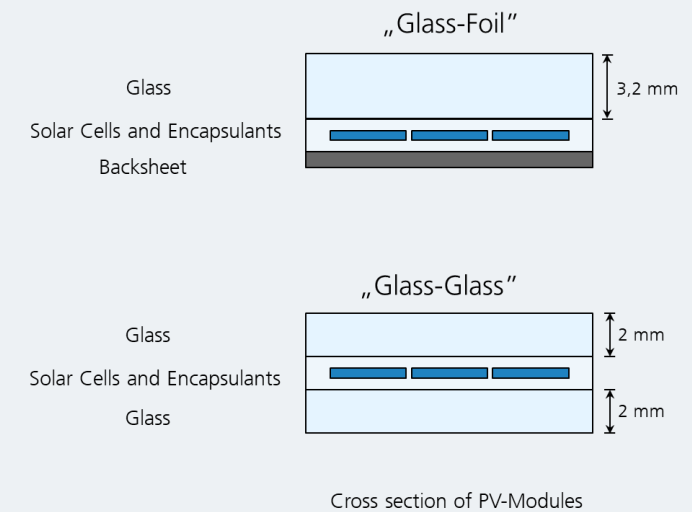
Overhead certified PV modules



Glass Glass
PVB



- Mechanical requirements: FEM simulations and mechanical load tests (IEC 61215)



- Industrial glass/glass PV modules with overhead certification are commercially available

Contact

Martin Heinrich, Jacob Forster
PV Modules – Road Integrated PV
Tel. +49 761 4588-5024
Martin.heinrich@ise.fraunhofer.de

More Information

Current Projects on "Road Integrated PV"

"PV 500" – PV Roofing Over Roads
Within the project, PV 500, a demonstration for the roofing of roads with PV systems is being developed and tested, with following targets:


- Energy generation by photovoltaic modules: up to 150 kWh per year per roofed square meter
- Possible use in the road infrastructure (e.g. at toll areas, toll facilities, tolls control areas, bridges, tunnel portals)
- Increase of road safety (road conditions, lighting)
- Protection of the road surface against the effects of the weathering
- Additional noise protection

"Paves" – Development of Wall-Integrated PV Elements for Noise Protection
Within the ePaves project, PV modules are being developed for integration into noise barriers on roads and railways.

- PV module assemblies for additions, modifications, and new barrier construction
- Development and testing of sound-absorbing and sound-insulating module concepts
- Concepts for efficient and safe electricity use

Further Information on Current Projects

Project website: [ePV 500](#) Project website: [ePaves](#)



Integrated Photovoltaics

Solar Energy from Traffic Infrastructure

Contact

Dr. Martin Heinrich
Road Integrated PV
Phone: +49 761 4588-5024
martin.heinrich@ise.fraunhofer.de

Fraunhofer Institute for Solar Energy Systems ISE
Heinrichstr. 21
91030 Erlangen, Germany
www.ise.fraunhofer.de

© Fraunhofer ISE, Freiburg
09/2021

Solar Energy Potential of Transportation Infrastructure

Electricity from photovoltaic systems is an essential component of the energy transition. To generate sufficient energy, large areas have to be equipped with solar modules. Here, road infrastructure can offer a large area of potential.

To realize this potential, we are working together with interested providers of suitable photovoltaic and infrastructure systems, as well as with potential power plant operators and electricity consumers.

At Fraunhofer ISE, we develop and test suitable technologies for a wide range of requirements. Integration of photovoltaic (PV) is possible in these areas:

- Noise barriers and walls
- Roofing of roads
- Surrounding areas of road and rail traffic
- Paving of public squares, footpaths, cycle paths and over crossings of railway tracks

Photovoltaics in the transportation sector can be added to existing infrastructure or installed in new constructions. In Germany, 5 % of the country's surface area is covered by transportation infrastructure (e.g. roads, car parks or noise barriers). According to current studies, this results in a technical potential of 200 Gwatts of additional PV power. For comparison: By the end of 2020, solar systems with a total capacity of 16 Gwatts had been installed in Germany.

Our Services

- PV technology consulting and cost optimization
- Potential design and development
- Demonstration of the solar energy yield
- Module installation
- Power yield and cost analysis
- Contribution and management of R&D projects with industrial partners

Technical Challenges with Planning and Installation

PV components and systems for integration into roads have to overcome a number of application-specific challenges that are not encountered with common ground-mounted PV systems.

- Glare-free photovoltaic structures with low sound transmission and reflection for noise protection
- Diverse, traffic-safe construction and low weight per unit area for roadways
- Robust, non-dip modular structures for the pavement integration
- Safe maintenance systems and long service life under high loads
- Low loss electricity transport along the infrastructure to the consumer

Creating Opportunities through Solar Installations on Roads

- Photovoltaic development over sealed surfaces, without additional land consumption
- Savings through protective functions (e.g. noise protection, weather protection)
- Power generation for transport infrastructure (e.g. charging stations, overhead lines, service stations or other local consumers)
- Return on investment with infrastructure projects
- Contribution and management of R&D projects with industrial partners

We meet the challenges with our many years of experience in manufacturing industrial modules in our "Module-PEC - Module Technology Evaluation Center" and with extensive analysis procedures.