Photovoltaics fused with the urban environment

Solar Urban

SOLAR URBAN

The Solar Urban research programme is a cooperation between Delft University of Technology and the Amsterdam Institute for Advanced Metropolitan Solutions

Solar Urban: real solutions for the full-scale integration of photovoltaics in the urban environment

To realize the energy transition, full-scale integration of renewable energy sources is required. Specifically, for the urban environment, photovoltaics energy generation is the most widely applicable solution. In the Netherlands, around half of the total annual electricity demand can be generated in the urban environment using photovoltaics.

The Solar Urban research programme was initiated to support a full-scale fusion of photovoltaics in the urban environment: not simply the application of the technology in cities, but the ingraining of energy generation, use and storage in urban living. As such, the programme accelerates the implementation of sustainable energy approaches and a circular economy, a core element for future smart resilient cities.

Solar Urban involves not only technology innovators and photovoltaics companies, but also architects, designers, construction and energy companies, municipalities and citizens to achieve an integration that benefits us all. By combining expertise in photovoltaics, design, building technology, circularity and urban integration, Solar Urban is a platform and partner for private and public stakeholders to cooperate with and for students to flourish in. With strong links to the city of Amsterdam, the programme tackles real urban issues and provides realistic solutions which can be tested within the city.

Solar Urban is a cooperation between the Faculty of Architecture (group Climate Design & Sustainability) and the Faculty of Electrical Engineering, Mathematics and Computer Science of TU Delft (group Photovoltaic Materials and Devices) of Delft University of Technology and the Amsterdam Institute for Advanced Metropolitan Solutions (AMS). The programme is also part of the Urban Energy platform of TU Delft.

The Solar Urban programme takes on challenges such as enabling electricity generation close to where it is consumed, utilizing many different urban structures for photovoltaic integration, developing photovoltaics-integrated products and tackling problems that are relevant to our cities like the urban heat island effect. The programme is divided into three research lines, depending on the level of technology implementation:

- Ingraining photovoltaics in urban living
- Integrating photovoltaics in urban structures
- Adapting photovoltaics technology

Focus areas

Each research line is designed to address the following focus areas at once:

1. **Maximizing the technical and physical potential** of solar technology in the built environment for multiple purposes, not just for solar electricity generation but also for shade tolerance, carbon uptake and conversion to gases for storage and transport, or innovative air-conditioning for the built environment.
2. **Design and architectural engineering** of photovoltaics-integrated elements, in compliance with architectural requirements for both existing and new buildings and urban surfaces.
3. **Development of circular materials and components** for photovoltaics-integrated elements, paying attention to processing methods and component structures that hold promise for low-cost circular manufacturing.

How we work

Research line 1

Ingraining photovoltaics in urban living

To ingrain a technology in urban living, the implementation must feel natural and accepted by everyone in society. All stakeholders should be involved to make the full-scale integration a success: not only technology innovators and solar-cell companies, but also architects, designers, construction and energy companies, municipalities and citizens. In a crowded urban area, every space is spoken for and has a purpose. For maximum integration of photovoltaics and solar thermal ('PVT') technologies in a city, any surface that is illuminated by the sun must be used.

Large-scale implementation of solar energy innovations in the urban environment necessitates multifunctionalities in the application. This implies that a structure such as a building construction, road, pavement, pergola, bicycle parking or sun screen, is also used for the generation of electricity.

But ingraining of a technology does not stop here: pressing urban issues should be tackled as well. Can the implementation of large-scale PV(T) applications reduce issues like the urban heat island effect or graffiti? If so, how can the technology be best used to reduce the specific urban issue? How can the grid be optimized? How should the heating network be organized? How should districts be organized to optimally handle generation and use of energy? How can installation costs be reduced when realizing large-scale innovations? How can one successfully implement solar energy everywhere with consent from citizens? How should PV implementations be shaped and adapted to fit society's demands? These and more research questions are tackled in this research line.

A home with a skin is a real solution, for real people in the Netherlands

The post-war row house, built in great numbers for the European middle class, is a major consumer of energy. With over 1.4 million homes, this type of house dominates the Dutch building stock. How do you improve the outdated climate and spatial conditions of these existing buildings, with so many people living in them? This was the challenge TU Delft students decided to tackle when competing in the 2014 Solar Decathlon Challenge. Under the name **Prêt-à-Loger** (see photo previous page) they developed a 'skin' that can be put over a house to render it more energy neutral and to add more space, while its home quality remains untouched. Under the motto 'Improve your house, preserve your home', Prêt-à-Loger aims to enhance the performance of outdated dwellings while preserving the original feeling of the community and neighbourhood.

After the Solar Decathlon Challenge, where the initiative won top honours, it found a new home at TU Delft's Faculty of Architecture. *www.pretaloger.eu*

Modular office renovation with a net positive effect

After their success in the 2014 Solar Decathlon Challenge, TU Delft students take part in the 2019 edition as well.

In the modular office renovation (**MOR**) project, the students aim to address the looming housing crisis in major Dutch cities by transforming vacant offices into housing and flexible work spaces; a cost-effective renovation which is also net positive with regards to energy (using PV), water, air and biomass. To this end, they introduce a modular system consisting of four elements; a facade module, wall modules, a kitchen/bathroom module and a bedroom/workstation module. By combining modules, housing units of 25, 50 or 75 square meters are created. Modularity and prefabrication are necessary to achieve the circular economy principles. The off-site production provides opportunities to reduce waste during the construction phases of the project. Finally, the MOR modules are demountable, so that buildings can be returned to their original function. In these cases, the materials used could be disassembled and reused or recycled.
www.mor.tudelft.nl

Research line 2

Integrating photovoltaics in urban structures

Ingraining a technology in society not only requires a bird's-eye view of technology integration, it must also be developed in the required multifunctional structures. The specific question how a solar technology can be integrated in a structure such that multiple uses can be combined is the focus of this research line.

In a city environment, surfaces are widely different and can be divided into infrastructure elements, building elements and district design. For infrastructure and transport, the surfaces include roads, noise barriers, lamp posts, stairs, railway system, e-bike or car charging stations, trains, cars and buses. For building-integrated solar technology, the surfaces include roofs, facades, walls and floors. On the district level, one can think of integration and design-matching like integration in parks, matching designs of roads and buildings. For all these surfaces, questions arise on how these elements can be made aesthetically and architectonically pleasing, using circular materials and components and how the many set needs and requirements can be combined.

Building-integrated solar technology

Building integration of technology harvesting the electrical and thermal energy from the sun is commonly abbreviated to BIPV(T). Multifunctionality in buildings means that PV(T) is combined with functions such as heat/cold insulation, ventilation, sound insulation, stiffness, water and wind-proofing and energy storage. Multifunctional building elements limit discomfort and require less space, costs (build and installation) and installation time. Critical in the integration of elements is that the lifetime of each product is compatible to each other. This also holds for their environmental performance, including embodied energy and circularity. In this research line R&D topics are partly technical (like modularity and connections), but also involve standardization, interchangeability, certification and (re)assurance of performance.

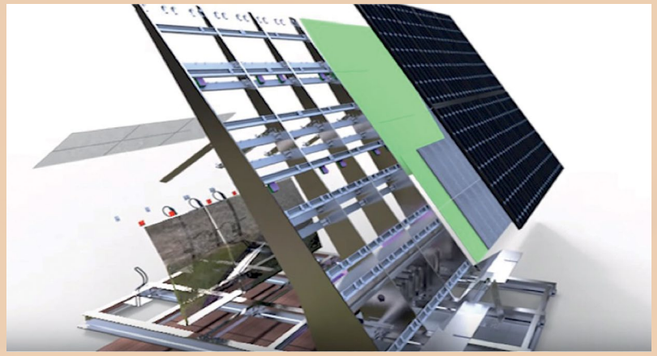
Architectural integration

Photovoltaic innovations can be integrated in such a way that their appearance is more favourable and in line to the architect's wishes. The colour of photovoltaics modules can be adapted, a pattern can be printed and added to the module, the metal lines on the cells can be applied in any shape desired. The solar cell module can be fabricated in any shape, moving beyond the well-known rectangular shape. We take the integration a step further: starting from the building needs and wishes expressed by architects or customers, we will innovate the photovoltaics application to make them as attractive as possible.

On-campus charging station

TU Delft recently developed and realized an **e-bike charging station** that solely uses solar energy. The charging station has eight solar panels with a total peak power of 2.3 kilowatts, and features a 10-kWh storage unit for cloudy days. During summer, the station will deliver its excess power to the grid. The solar charging station has connections for four e-bikes or e-scooters with three different connections: 48-volt DC, 230-volt AC or a wireless connection through the e-bike's kick stand which functions as an antenna. The station also has a weather station to monitor the outside climate as well as temperature sensors to monitor the temperature levels of the solar panels.

www.solarpoweredbikes.tudelft.nl



Research line 3

Digitalization and multi-functionality of photovoltaics technology

Whether on the level of the city or of a structure, far-stretching demands are placed on PV(T) technology. To meet these demands, the photovoltaic technology itself has to become intelligent and multi-functional. This requires adaptation of the design, of the cells, the modules and the electrical connections requires various innovations. Design variations may include colour, patterning of metal lines, surface modification, 3D shaping and mimicking the appearance of different materials. Within this research line, insights into technology demands and technology adaptation are focus areas.

Smart photovoltaics modules

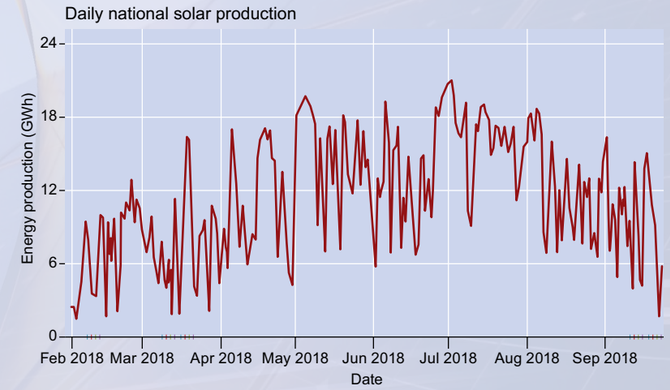
There is an increasing need to make modules smart, in order to tackle issues like shading and security (hacking) or to include possible adaptations such as additional batteries for storage or wireless power transmission. This calls for innovations in the electronics or in the modules' electronic design.

Advanced photovoltaics modelling

Adapting technology, integrating it in structures and ingraining in society require advanced modelling of PV(T). Within the Solar Urban consortium, modelling tools are available to model photovoltaics systems on the cell, module, system and city levels. On the cell level, ray tracing, coherent propagation, polarizations and the effects of the angle of incidence can all be modelled. Besides 'standard' modules, bifacial modules (from the cell level up) can be modelled as well. Finally, modelling of full systems, including 3D mounting effects, can be done.

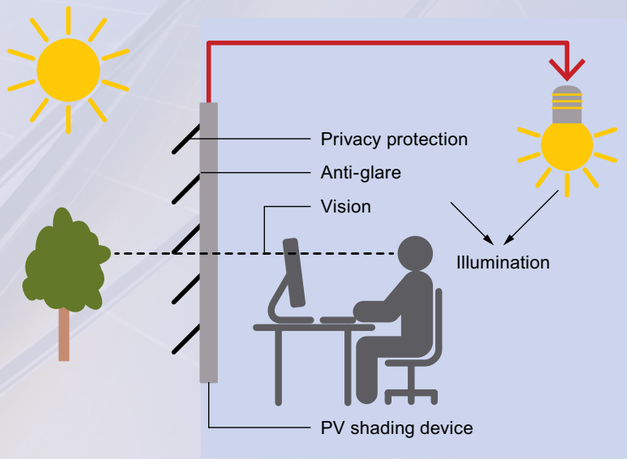
Photovoltaics data portal to support modelling

The **Dutch PV Portal 2.0** has been created to provide publicly accessible information on solar energy in the Netherlands, based on scientific research performed by the Photovoltaic Materials and Devices (PVMD) group at Delft University of Technology. The website combines the modelling expertise of the PVMD group with real-time and historical weather measurements of the Royal Netherlands Meteorological Institute (KNMI) to create a realistic assessment of the potential for solar energy generation in the Netherlands.
www.tudelft.nl/pvp2



PV windows

Nowadays, building-integrated photovoltaic (BIPV) is beyond just simply fixing PV panels on roofs. PV materials are more likely to be contained within the building envelope, or as a functional component of the building. Since modern buildings have more vertical areas than horizontal areas, windows become potential channels to harvest solar energy. Besides power generation, window-PVs are also involved in such building functions as daylighting control, privacy protection, open view, glare prevention, etc. TU Delft designs integrated PV materials to interact with window treatments (such as blinds, shutters and films). Optimal lighting and energy control are also studied based on such designs. The purpose of designing such PV windows is to provide occupants with a healthy and comfortable working and living environment, besides power generation for net-zero-energy buildings.



Research expertise

The Solar Urban research programme is a multidisciplinary cooperation between Delft University of Technology (TU Delft) and the Amsterdam Institute for Advanced Metropolitan Solutions (AMS).

TU Delft

Faculty of Electrical Engineering, Mathematics and Computer Science – Photovoltaic Materials and Devices (PVMD) group

The PVMD group, led by Prof. Miro Zeman, focuses on the development of photovoltaic technologies throughout the whole value chain. Researchers work to develop thin-film and wafer-based solar cells, investigate innovative materials for cells and modules and realize new concepts for photovoltaics applications. This broad focus within the group leads to a thorough understanding of the technical possibilities and physical limits of the system and allows easy manipulation of one part of the chain (like cells) to accommodate wishes in another part (like architectural design). This helps the group to realize its leading strategy to implement solar energy everywhere.

Faculty of Architecture – Climate Design and Sustainability (CDS) group

The CDS group, led by Prof. Andy van den Dobbelsteen, focuses on the realization of a future in which we are prepared for extreme weather conditions, independent from fossil fuels and using only materials from the circular economy. Their wide view on how a city should be organized incorporates the organization of energy networks, urban planning down to the design of a building, incorporating renewable technologies like solar energy. The multidisciplinary approach needed to realize the goals, requires input from architects, building technologists, physicists, urban planners, construction specialists and industrial ecologists, who are all represented in the CDS group. Together, these experts aim to integrate sustainable climate concepts in architectural design and urban planning.

Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute)

AMS Institute is a young and ambitious scientific institute located in Amsterdam, strongly supported by the Amsterdam municipality and its resources. At AMS Institute, science, education, government, business partners and social organizations are working tightly together to create solutions for the complex challenges a metropole like Amsterdam is facing. The challenges are centred on applied technology in urban themes such as water, energy, waste, food, data and mobility, and the integration of these themes – now and in the future. AMS Institute is positioned at a unique crossroad between fundamental sciences and the society-wide application of truly innovative solutions for metropolitan challenges. Bringing together the brightest minds in the field, AMS' innovations have a state-of-the-art research core and are tested and demonstrated in pilot projects and experiments throughout the city of Amsterdam as living lab. Moreover, all innovations are developed and tested together with local, national and international private and public partners, citizens and its future users within the city of Amsterdam as a unique testing and piloting place.

For students

The Photovoltaic Materials and Devices group at TU Delft operates a photovoltaics laboratory (PVLAB) where students can participate in unique practical courses, working with real system components, taking measurements and performing analysis. It offers graduation projects as part of outstanding world-class research in areas such as photovoltaic electricity generation; fabrication and characterization of new energy materials; design, fabrication and testing of highly-efficient and environmentally-friendly components such as solar cells and modules, inverters and electro-mechanical machines; and design and optimization of complete electricity power systems with novel smart grid architectures and system-performance monitoring.
The Climate Design and Sustainability group is responsible for all climate design education at the faculties of Architecture and Civil Engineering & Geosciences of TU Delft. It participates in interdepartmental and inter-university Master's degree courses, like Industrial Ecology. Graduation projects deal with climate design in general, relying on fundamental knowledge of building physics (heat, air and moisture, sound, light, sun and wind) and of building services engineering (installation concepts and components), combined within a context of sustainable building design.

For public and private partners

The Solar Urban programme is open to cooperation with public and private partners, using part or all expertise available. Collaboration is welcomed, from ideas, issues or wishes all the way to the realization of demonstrators for large scale implementation.
Please do not hesitate to contact us. You are most welcome!

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