2/2017

# energy innovation austria

Current Developments and Examples of Sustainable Energy Technologies

## Photovoltaics - a key technology

### Innovations from Austria for tomorrow`s power supply

With solar energy in almost unlimited supply – at no cost – photovoltaics (PV) technology is one of the most attractive ways to generate renewable sources of energy. It looks as though this technology will go on developing dynamically in the future, gaining real importance for the entire energy supply system. In Austria work is currently in progress on pioneering, low-cost products and manufacturing methods within the framework of various flagship projects in energy research, with the aim of opening up new markets for the PV sector and permanently securing the technological position of Austrian suppliers internationally.

*Flexible PV foil*
*Photo: crystalsol GmbH*

# Photovoltaics technology in Austria
## Development and perspectives

Widespread deployment of photovoltaics (PV) is one of the key factors in the expansion planned by the European Union (EU) for energy from renewables. In 2011 the EU Commission mapped out, in their "Roadmap for moving to a competitive low-carbon economy in 2050", ways intended to lead to a reduction of carbon-dioxide emissions by 80 to 95 % as against 1990; the power-supply sector should achieve zero emissions by 2050. At the 2015 Climate Conference in Paris Austria tabled the target of 100 % power supply from renewables as early as 2030.


Photo: TU Wien

Throughout the energy industry there is a marked trend to electricity as the preferred form of energy supply. In all probability electricity will be increasingly important in tomorrow's energy mix, and both heat and fuel will be obtained from power from renewables to some extent, while more use will be made of electricity in industry and the transport sector.

PV technology is extremely reliable, with plenty of potential for further improvements in efficiency. So far Austrian firms and research institutes have secured a strong position in the PV sector around the world. Rapid growth in the market for PV modules over the last few years has led to a dramatic drop in prices. Today we have fierce competition between PV modules based on standard crystalline silicon technology and on emerging technologies (e.g. Perovskite, Quantum-Dot PV und concentrated PV) and between the production locations Europe and America versus Asia. To secure Europe's and Austria's technological lead in the long term, more investment is needed in developing new products and manufacturing processes. The main challenges include diminishing material and energy consumption in producing PV modules and developing cutting-edge products and applications, so as to open up new markets.

With the support of the Climate and Energy Fund and the Federal Ministry for Transport, Innovation and Technology (bmvit) various large-scale R&D projects in the field of PV are currently under way in Austria, with numerous Austrian firms and research partners collaborating. Here we present some of these pioneering projects.


*Flexible PV foil , Photo: crystalsol GmbH*

*Photo: crystalsol GmbH*

### Technology Roadmap for PV in Austria

The technology roadmap published by bmvit in 2016 indicates what PV can contribute in an energy scenario based entirely on renewables by 2050 ; the focus here is on building and urban development, industry and energy infrastructure. In 2016 PV facilities to the tune of around 1 GW were in place in Austria, covering just under 2 % of Austria's power consumption. 85 % of the PV facilities installed in Austria are mounted on roofs, 2.4 % are integrated in roofs or façades, and 11.7 % are positioned on open ground.

In 2015 PV modules with a total power of around 115 MW were produced in Austria. The Austrian PV sector employs roughly 3,500 people. Around 97 % of domestic production of power inverters (587 MW in 2014) is exported, and Austrian firms are equally successful in exporting in the fields of cell encapsulation, backsheets, installation systems and various other accessories for the PV industry.

If we assume that the energy system will undergo a massive shift towards electricity, while the transport system and all major industrial processes are adapted accordingly, PV can provide around 15 % of Austria's power consumption by 2030, and around 27 % by 2050. Enough space for PV on this scale is already on hand on existing roofs and façades, even at today's efficiency factors. The central challenge here, in both engineering and legislative terms, is to make the power system fully flexible.

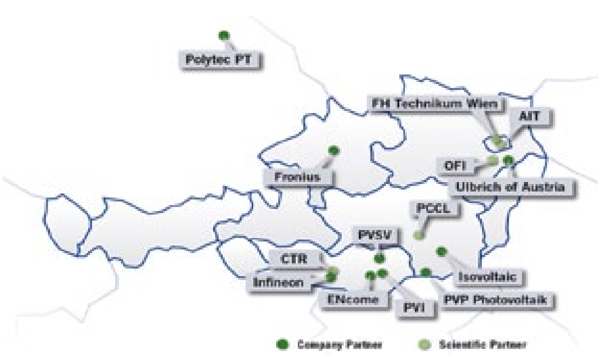
# INFINITY
# PV systems for regions with differing climates

*PV modules in a subtropical climate/Qatar, Photo: ENcome Energy Performance GmbH*

Today standard PV modules are in use in almost all climatic zones (temperate and alpine zones, the tropics or deserts). So far the differing climatic conditions and their effect on the PV system have been more or less ignored in technological development. Damage may occur, leading to loss of yield and a reduction in service life. In the flagship project INFINITY, headed by the research centre CTR Carinthian Tech Research AG, five scientific partners and nine industrial firms are jointly investigating how long PV systems last in various climatic zones. The aim here is to improve the entire system and adapt it to the particular climatic and regional requirements applying. The consortium deals with all aspects throughout the value-creation chain, from PV materials and components via module production all the way to installing and servicing PV facilities. The research partners contribute their scientific expertise in order to develop pioneering approaches for various climatic zones and regional specifics, such as unstable power grids, say. The firms involved utilize the research findings to develop new products for the global market.

## Improving the system overall

To start with, the project partners analyse the sources of trouble and the processes which degrade the PV materials, components and modules in use today. On the basis of these analyses new versions of all system elements are developed (e.g. backing foils, connecting leads, power inverters, etc.), while conditions adapted to the location in question are drawn up for monitoring PV systems effectively and servicing them. The aim is to implement PV modules with an extended service life (adapted to the climate in question) that generate more power at constant rates; European products can thus be kept competitive.




*Research Partners, Graphic: CTR Carinthian Tech Research AG*

*PV modules in the Alps/Obervellach Photo: ENcome Energy Performance GmbH*

*PV modules performing in the tropics/Bora Bora, Photo: Fronius International GmbH*

## Current research issues

In the first year of the project the focus was on identifying and analysing actual damage to PV materials, components and modules that had deteriorated in the field in various climatic zones. On the basis of the "Failure survey sheet" used in the IEA's PVPS Task 13 technology programme a database was built, covering 354 surveys of more than 100 PV facilities and documenting a total of 561 different types of defect in/damage to PV systems in common use.

250 sample modules (single-cell or six-cell) have undergone laboratory testing. Damage due to particular climatic conditions has been simulated by means of accelerated aging tests under various stress regimes. The modules' degradation behaviour has been analysed, and a model developed for describing the interrelations between climatic zone, aging and length of service life. In the light of the particular load factors involved various backing materials, backsheets, PV strips and adhesive formulae are improved.

Adapting power inverters to extreme climatic conditions is a further area of research. Various approaches to optimizing these have been investigated, and the findings summarized in a roadmap. This involves analysing the effects of sand and of condensate forming on or in power inverters, for instance, or the influence of cosmic radiation on the power electronics. Ways to improve polymer materials in power inverters are also being investigated as part of the project.

Initial findings from this research have already been discussed at 15 international congresses and symposia and presented in various publications. Work is in progress on a patent application. ◘

Flexible PV foil, Photo: crystalsol GmbH

# flex!PV.at
## Approaches to producing ultra-efficient flexible PV modules

Current R&D activities in the PV field are focussed on completely new PV technologies based on organic, anorganic or hybrid active layers. These cutting-edge module designs are semitransparent and flexible, and their mass per unit area is low. The new technologies might have considerable potential in the PV market, provided that the very promising research results so far can be transferred successfully from laboratory scale to industrial production. Vital expertise in developing materials and cells, in coating technology, module development, cell encapsulation and module testing has been brought together in the project flex!PV.at.

The project consortium was made up of the research partners NTC NanoTecCenter Weiz (now JOANNEUM RESEARCH Materials, heading the project), AIT Austrian Institute of Technology, LIOS Institute for Organic Solar Cells at Johannes Kepler University (JKU) Linz, ICTM Institute for Chemistry and Technology of Materials at Graz University of Technology, and Fraunhofer Institute for Applied Polymer Research (IAP), plus two Austrian firms, crystalsol GmbH (Vienna) and ISOVOLTAIC AG (Lebring/Styria).

### Project focus

The aim of flex!PV.at was to develop pioneering designs and materials, and low-cost, resource-conserving processes for continuous production of thin-film solar cell modules. From depositing the absorption layer, the intermediate/buffer layers, via thermal treatment to dry the layers, all the way to printing the electrodes and continuously encapsulating the modules, every single step in production was investigated from several technological angles. Here expensive raw materials in short supply, such as indium, and cost-intensive, energy-guzzling vacuum processes should be avoided. Suitable approaches were worked out for two very different PV technologies: on the one hand for organic solar cells with material layers less than 500 nm thick and low-temperature processes below 200 °C, and on the other hand for anorganic solar cells based on copper-zinc-tin-(sulfide/selenide) with material layers in the micrometre range and high-temperature processes above 350 °C.

### Technical challenges

> Researching alternative cell and module designs to make solar cell modules flexible
> Closing the gap between cell and module efficiency
> Developing solution processes for transparent electrodes
> Ultimate transition to an entirely continuous process
> Developing solution-processed cadmium-free buffer layers
> Extending module service life

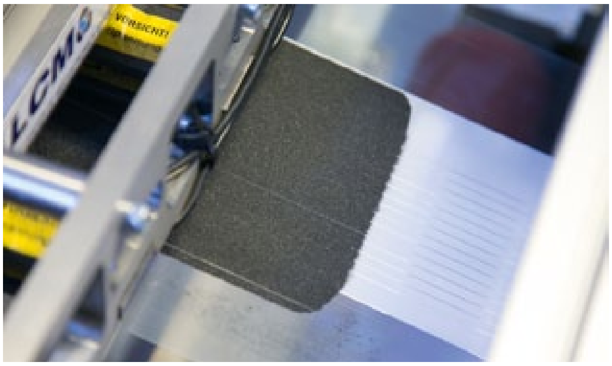
### Milestones

In the course of the project very promising results were achieved, i.e. significant milestones for future production of the new flexible thin-film solar cells. A strategy for boosting module efficiency while providing considerable flexibility was successfully implemented both for anorganic and for organic cells. The efficiency loss between cell and module is reduced from about 50 % to 30 %.

Other successes are the effective integration of the solution-processed production of transparent conducting electrodes and the development of cadmium-free buffer layers in the fabrication of solar modules and cells. As part of the final transition to an entirely continuous process, stable solar cell modules were produced and tested under real-life conditions. All the individual components of the solar cells and modules were assessed in terms of durability; adapting the materials and processes employed and finding the most suitable encapsulation resulted in extended service life up to 20 years.

### flex!PV_2.0

In a follow-up project headed by AIT Austrian Institute of Technology, which started in 2016, emergent thin-film PV cells based on kesterite and perovskite absorber layers free of heavy metals are investigated. The research is focussed on material development, the coating process and the most suitable module design for future industrial mass production.



*Test runs for print.PV at crystalsol GmbH*
*Photos: crystalsol GmbH,*
*Helmut Mitter www.helmut-mitter.com*

# print.PV
## New fabrication process for flexible PV foil

Two Austrian firms, crystalsol GmbH and Forster Werbetechnik GmbH, are currently at work on developing a novel “next generation” technology for fabricating flexible PV foil.

In the project print.PV the two firms are collaborating with numerous experts on material and process development; Austrian research institutes from the fields of polymer chemistry, printed electronics, photonics and thin-film technology, such as Polymer Competence Center Leoben (PCCL), JOANNEUM RESEARCH Materials and AIT Austrian Institute of Technology, are closely involved in this.

The pioneering PV technology is based on employing low-cost materials and ultra-efficient fabrication technologies from the printing industry. The medium-term aim is to be able to produce solar modules at a globally competitive price of 0.3 Euro/Wp in Austria.

The concept is to use a PV foil (already patented by crystalsol GmbH) with attractive new product characteristics, particularly as regards integration in buildings and appliances; it is flexible, light, and the foil runs are straightforward to make up. Dramatic savings in the cost of fabricating the foil should result from using a fully integrated, ultra-productive roll-to-roll printing technology such as flexographic printing.

*Photo: crystalsol GmbH*

*„Integrating PV in buildings provides a unique opportunity to combine local, environmentally sound energy supply with architecturally high-grade implementation. Façade and roof surfaces are available free of charge and – apart from the primary functions of the building envelope, such as protection against the weather and privacy – are most suitable for the new function of generating electricity. Our new, flexible PV technology is intended to make this possible at affordable prices.“*

*Rumman Syed, CEO*
*crystalsol GmbH*

*Photo: crytsalsol GmbH*

*Photo: crystalsol GmbH*

This approach involves major technological challenges; various steps in the roll-to-roll printing process must be replaced by new, pioneering methods:

> Increasing belt speed for precipitation on the solar modules by a factor of ten, to 40 m/min
> Halving the quantity of absorber materials used
> Avoiding cost-intensive vacuum processes
> Contact materials to be free of precious metals such as silver

The novel processes have been tested on a laboratory scale at crystalsol GmbH in Vienna; test runs under real-life conditions are currently in progress on printing presses at Forster Werbetechnik GmbH in Waidhofen an der Ybbs (Lower Austria).

With the project successfully carried out, the foundation has been laid for producing flexible PV foil at competitive prices in Austria; the Austrian PV and printing industries now have the chance to play a leading role in the expanding world PV market. ◘

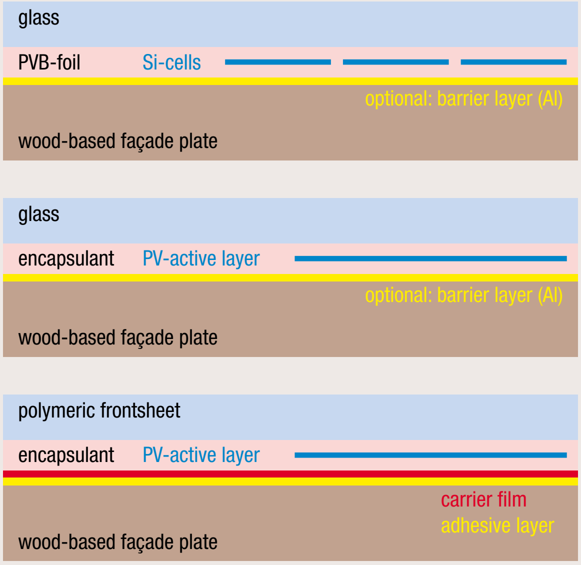
*PV test façade,*
*Photo: Michael Grobbauer,*
*SFL Technologies*

# PV@Fassade
## Façade elements with PV-active layers

PV@Fassade is a project in which experts from science and industry do research on efficient, aesthetically appealing components and systems for PV integrated in buildings (BIPV). Particularly in Austria, where open space is mainly used for agriculture, buildings offer the largest potential for installing PV facilities. In future more use can be made not just of roofs, but also of façades, balconies and canopies to integrate PV modules.

BIPV modules based on crystalline silicon technology and glass/glass structure have been in use for years and proved themselves efficient and reliable. In Austria only around 2.4 % of all PV facilities are integrated in the building envelope, and only 0.6 % in the façade. But for innovative PV technologies with new backing materials there is a lack of technically, economically and aesthetically satisfying ways of integrating these in buildings, particularly façades. BIPV involves special challenges both in terms of design, circuitry, materials and appearance and as regards the efficiency and durability of the PV components.

**Construction of BIPV façade elements**




*Grafic: OFI Österreichisches Forschungsinstitut für Chemie und Technik*

### Aims in research

PV@Fassade is an interdisciplinary project in which nine Austrian partners from industry and research, headed by OFI Österreichisches Forschungsinstitut für Chemie und Technik, are developing solutions to the complex problems involved in building-integrated PV, in order to create the knowledge and technology base necessary to implement low-cost, reliable, aesthetically appealing BIPV systems. Research work includes developing improved PV active materials (crystalsol GmbH, Sunplugged – Solare Energiesysteme GmbH) and ways to laminate/bond them with a façade element (compact panel) developed by the firm of Fritz Egger GmbH to form a durable multi-material composite. Another important issue: working out pioneering circuitry and integration approaches for more efficient PV façade elements.

Linking up PV technology and architecture is a vital aspect here. Developing new options for PV modules' appearance and colour is part of this; the aim is to make the appearance of PV on buildings more acceptable to future users. The approaches worked out will be discussed with architects, students and users, evaluated at JOANNEUM RESEARCH Materials (a partner in research) and incorporated in the process of improvement.

simlpiciCIS flexible thin-film solar cells,
Photo: Klima- und Energiefonds/Ringhofer

Community centre in Ludesch with glass/glass modules fabricated by ertex solartechnik GmbH, Photo: GR Gebhard Bertsch

## Current findings

Important results have already been achieved in all the key research areas. The visual appearance of the PV façade elements is a vital issue. The glass surfaces (ertex solartechnik GmbH) or solar cells (JOANNEUM RESEARCH Materials) in the module can be printed or stained to produce a wide variety of hues. What influence this has on PV element performance has been ascertained experimentally at AIT Austrian Institute of Technology. Numerous processes for coating crystalline silicon solar cells have been tested and various colour patterns generated. CZTS (copper, zinc, tin, sulfur) thin-film PV foil from crystalsol GmbH has also been adapted to the requirements of integration in buildings and made up in multi-coloured patterns. Sunplugged - Solare Energiesysteme GmbH are currently at work on improving CIGS (copper, indium, gallium, selenid) PV foil.

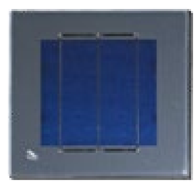
As regards lamination with PV encapsulating materials, the most suitable settings for polyvinyl butyral (PVB), to bond the façade plates to the PV-active layer, have been identified at ertex solartechnik GmbH, where multi-material composites have been fabricated with compact façade plates from Fritz Egger GmbH. New approaches for installation and for electrical lines have been developed, and an improved system from Pasteiner Fassadenbau GmbH was adapted for the façade elements.

The sample modules produced have been installed on the façade of a miniature tower and on a large-scale test façade; they can now be evaluated in situ. On the tower the various cell technologies are being assessed by the CTR Carinthian Tech Research GmbH to see how the direction of insolation influences performance, for instance. At SFL technologies GmbH in Stallhofen in Styria eight trial façade elements (1 m x 0.7 m) have been installed on the test façade. To evaluate the PV elements‘ performance and stability under real-life conditions, the yields from the individual modules, plus meteorological data, are being recorded over a full year by means of instrumentation specially developed by AIT.

*„In a three-year research and development phase pioneering BIPV elements featuring three different cell technologies have been developed. PV-active layers have been successfully joined to façade materials such as a compact plate based on wood to form a multi-material composite that delivers electricity; this points the way ahead for developing new BIPV elements.“*

Photo: OFI

*Gabriele Eder*
*OFI Österreichisches Forschungsinstitut für Chemie und Technik*



*From left: sample modules with CIGS technology from Sunplugged, with CZTS technology from crystalsol and with crystalline Si technology, fabricated at ertex Solartechnik GmbH, Photos: OFI*

By CTR a sensor system for key variables such as humidity, temperature and mechanical strain is being developed for integration in modules.

Experts at the OFI Österreichisches Forschungsinstitut für Chemie und Technik are assessing how compatible the materials of the components employed in the modules are. In the course of accelerated aging tests the chemical, thermal and mechanical stability of the materials in multi-material composites turns out to be a major challenge. Work is currently in progress on improving durability. ◻

# IEA PVPS
# Photovoltaik Power Systems Programme

Photo: ÖGUT/Petra Blauensteiner

Within the framework of the International Energy Agency's (IEA) technology programmes Austrian experts from research organizations and industry play an active part in international study groups. PVPS is a programme covering all aspects of PV systems. **Task 15** is concerned with the increasingly important issue of **"Building-integrated PV"** (BIPV), a field of research linking energy systems, architecture and civil engineering together. Building-integrated PV has remarkable potential especially in building renovation. As active components PV systems can take the place of other elements, such as shading devices or roof cladding, etc., and thus play a significant part in sustainable urban planning.

As part of **Task 12** extensive information about **"PV Environmental Health and Safety"** and all dimensions of sustainability over the entire life cycle of PV systems is being edited for the general public and for policy makers. The Task is currently dealing with recycling production waste and worn-out modules, evaluating life cycles and operational safety.

*„Alongside examining cradle-to-grave environmental impacts it is also essential to take social aspects into account, in order to ensure that PV is implemented sustainably. Under the lead-management of the Austrian and Spanish representatives in Task 12 socio-economic aspects of PV will be investigated in the forthcoming period and a method of assessing these will be developed."*

*Susanne Schidler*
*Austrian representative IEA PVPS Task 12*
*University of Applied Sciences Technikum Wien*
*Departement of Renewable Energy*

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**Technology Roadmap for PV in Austria**
University of Applied Sciences Technikum Wien GmbH, AIT – Austrian Institute of Technology GmbH, JOANNEUM RESEARCH Forschungsgesellschaft mbH
Published by: bmvit
https://nachhaltigwirtschaften.at/de/edz/projekte/technologie-roadmap-fuer-photovoltaik-in-oesterreich.php

**IEA research collaboration**
www.nachhaltigwirtschaften.at/iea

IMPRINT
**Published by** Austrian Federal Ministry for Transport, Innovation and Technology, (Radetzkystraße 2, 1030 Vienna, Austria) in cooperation with the Climate and Energy Fund (Gumpendorfer Strasse 5/22, 1060 Vienna, Austria)
**Edited and designed by** Projektfabrik Waldhör KG, 1010 Vienna, Am Hof 13/7, www.projektfabrik.at
**For change of your shipping address contact:** versand@projektfabrik.at

Production minimizing impact on climate, FSC certified, Green Seal and Austrian Seal of Ecological Approval