The dye solar cell module is still a young photovoltaic technology. However, in the last few years, this technology has started to extend beyond the laboratory level. The ultimate aim is the successful integration of these solar modules into the building façade. A large challenge in the development of new photovoltaic technologies is the transfer from the laboratory to the industrial level. As a step in this direction, researchers at Fraunhofer ISE have succeeded in producing the worldwide first dye solar cell module on a continuous substrate material with dimensions of 60 x 100 cm². An important hurdle has been overcome.

Dye solar cells are photoelectrochemical solar cells. The conversion process is similar to photosynthesis. Unlike conventional solar cells, an organic dye is used in dye solar cells to convert light into electrical energy. In principal, they are simple to manufacture and present a prime example for the research behind and the realization of functionalizing nanomaterials. Dye solar cells are based on a nanocrystalline carrier layer made of titanium dioxide TiO₂ whose surface is chemically bonded with a monolayer of dye molecules. A small amount of gel electrolyte is used for the transport of the carriers.

Low-Cost Production
The modules are manufactured in a multiple screen printing process and are encapsulated and sealed using glass frit in a thermal fusing step; these procedures are closely related to methods used in the flat glass industry. The 6000 cm² modules manufactured recently at Fraunhofer ISE are therefore a big step towards cost-effective production of DSC PV modules.

Variable Design
Dye solar cells afford an interesting application for Building Integrated PV (BIPV) due to their flexibility in design, which opens new opportunities for façade design and advertising purposes. The modules, developed as prototypes, are of transparent amber color. With a filter this color can
be varied. The use of colored pastes highlights the pattern or gives the surface a homogeneous appearance. By printing with scattering coatings, any arbitrary images and text can be created with a negligible loss in electrical power.

Present State of Technology
A short time ago, efficiencies of 7.1 percent, with respect to the active area, were reached at Fraunhofer ISE for 10 x 10 cm² dye solar cell modules. The same manufacturing procedure was used for these small modules as for the up-scaled 6000 cm² modules. In the 6000 cm² modules, twelve solar cells are connected in series. By means of improved printing technology, we estimate that it will be possible in the next two years to realize total module area efficiencies of >5% for these modules. Currently, world record calibrated efficiencies for small scale (<1 cm²) dye solar cells are over 11%. Accelerated aging tests of more than 1000 hours under the most varied conditions show good long-term stability of the cells. Comprehensive tests, specifically for BIPV applications, must be carried out in further projects to certify the modules according to standardized tests. This can be done using the appropriate testing equipment available at Fraunhofer ISE.

Implementation and Realization
The on-going work on dye solar cell modules at Fraunhofer ISE is carried out within joint projects sponsored by the Federal Ministry of Education and Research (BMBF), the European Commission and the Ministry of the Environment, Baden-Württemberg. In the joint project “FSZ-Industrie”, marketable product concepts for use in building facades as well as for grid-independent applications are currently being optimized and demonstrated in prototypes. The value-added chain for dye solar modules, which includes a range of different expertise, is met by a consortium made up of members from the free enterprise.

The manufacture of the 60 x 100 cm² modules was carried out using industry-relevant procedures and machines. For applying the dye and the electrolyte, a customized, in-house development was necessary. Therefore, in cooperation with the Fraunhofer IAO in Stuttgart, Fraunhofer ISE developed a station for automatically filling and sealing the large area dye solar cell modules. With this apparatus, the further manufacture of modules for future demonstration projects is guaranteed, and a decisive step towards a pilot processing line has been accomplished. Fraunhofer ISE is now considering plans for a spin-off company so that first demonstration systems can be realized. Further businesses and investors are being sought to join a cooperation for manufacturing and marketing dye solar cells. New markets are opening up in the areas of nano-particles, pastes for screen printing and fine chemicals. The manufacturing can be integrated into existing flat glass processing. The new DSC technology offers good chances for the successful creation of lucrative product ideas and their realization.