Technological and ecological assessment of concepts for sustainable photovoltaics

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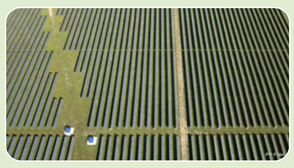
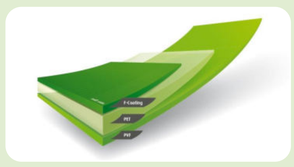
7 AFFORDABLE AND CLEAN ENERGY

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Vision and project goals of the Austrian flagship project „PV Re²"

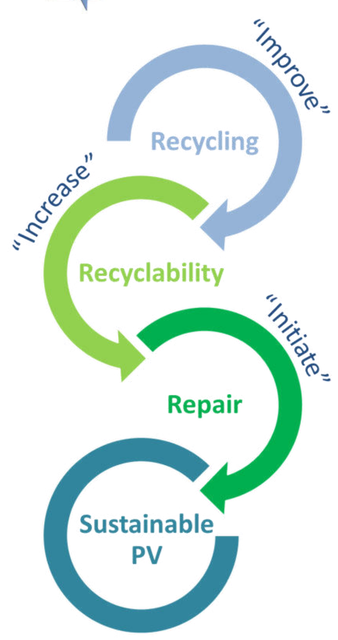
Repair of defective PV-modules to increase active lifespan of PV modules

Improved Recycling strategies & technology for existing PV modules

Material development and new module design for sustainable photovoltaics

Sustainable PV

PVRe²

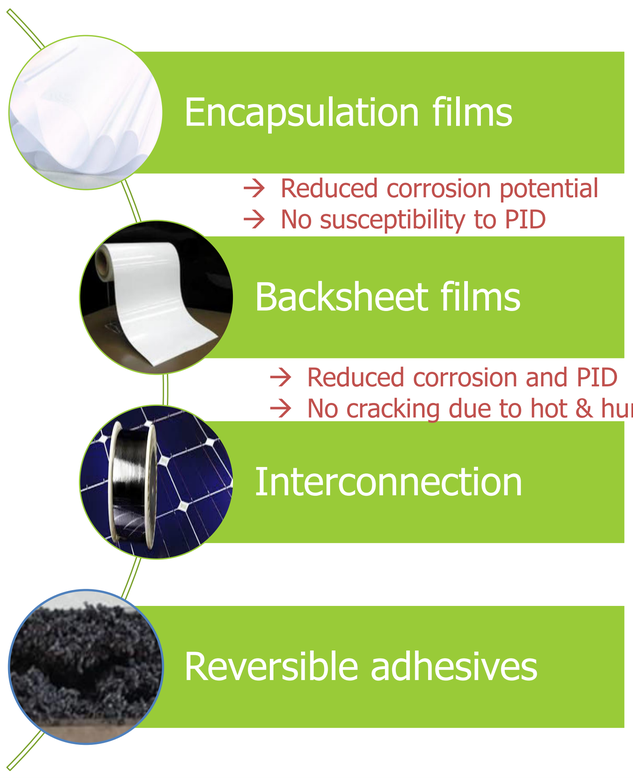


Motivation & Recycling potential

- **Enormous market growth: ~130 GWp of estimated PV production in 2019 [Jäger-Waldau, PV Status Report 2019)**
  - *China, Taiwan and Malaysia dominate module production market*
- **Annual growth rates between 30 and 40 %**
- **Total installed capacity > 6500 GWp (2018)**
  - *~ 75% installed in 5 countries (China, USA, Japan, Germany, India)*
  - *~ 120 GWp installed in EU; ~ 1.5 GWp installed in Austria*
- **Significant increase in global PV module waste is expected till 2050 [IEA PVPS Task 12, Report "End of life management solar photovoltaic panels]:** *From 45.000-60.000t (2016) to 60-78 mio t (2050)*
- **Special treatment of End-of-Life PV modules is only at the beginning of becoming an important issue due to the low amount of waste**
  - *Until now nearly no dedicated PV module recycling processes are available; State of the art: Shredding of PV modules, then recycling of glass*
  - *Eco-Design and recyclability have to become important in PV mass market*

Design of sustainable PV modules

- **General criteria**
  - *Reduced complexity of components: less material composites or material combinations*
  - *No hazardous materials (Pb, F)*
  - *Reduction of rare or high impact materials (e.g. Ag)*
  - ***"Recycling friendly"** architecture, materials and components (detachable joints, easily demountable setup of laminate)*
  - *Consideration of reparability and energy efficiency during processing*
- **Aspired lifetime: 30+ years**
- **Challenges**
  - *Assessment of long term stability*
  - *(In)compatibility with other module materials*

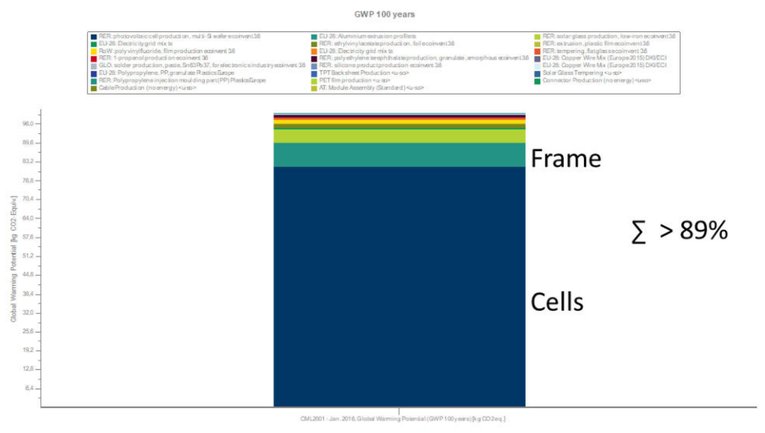


	Approach	Technological Benefits	Expected Ecological Benefits
Encapsulation films	***Thermoplastic polyolefin encapsulation film***	- *Elimination of corrosive degradation products and peroxide crosslinking process* - *No hydrolysis*	- *Increased recyclability & reparability* - *Reduced energy consumption due to reduced lamination times (<10min)*
→ Reduced corrosion potential → No susceptibility to PID			
Backsheet films	***Co-extruded polyolefin backsheet***	- *Selective permeability (low WVTR & high AATR)* - *No backsheet delamination* - *No hydrolysis*	- *Increased recyclability* - *Elimination of hazardous materials (Fluoropolymers)* - *Reduced energy consumption due to fewer processing steps (1x co-extrusion vs. min. 2x extrusion and 2x lamination)*
→ Reduced corrosion and PID → No cracking due to hot & humid conditions			
Interconnection	***Low temperature, lead free solders based on SnBi***	- *Reduced soldering temperature → can be used for new c-Si solar cell developments*	- *Elimination of hazardous materials (lead based solders)* - *Reduced energy consumption due to lower soldering temperature*
Reversible adhesives	***Adhesives with thermally expanding fillers***	- *Detachable joint*	- *Allows for easy recycling and repair of junction box or frame*

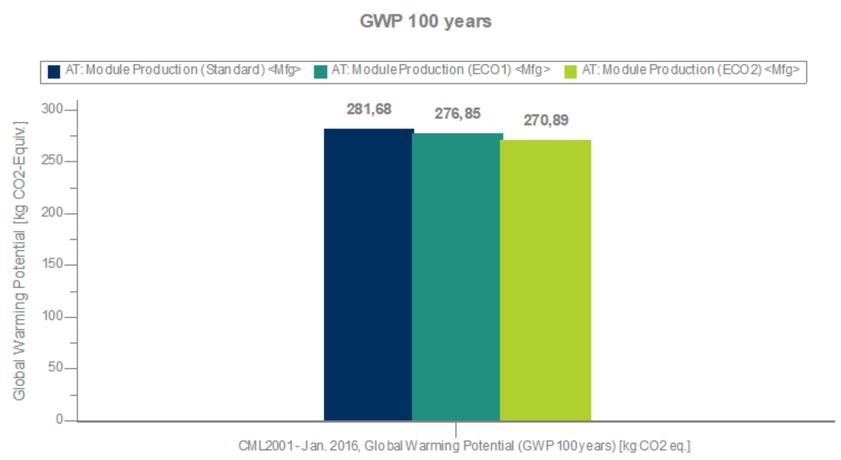
- **Comparison of 3 different module compositions - first focus on polymer packaging**
  - ✓ ***Standard Module:*** *crosslinking EVA encapsulant, PVF/PET/PET laminate as backsheet; 3.2mm front glass*
  - ✓ ***PV Re² Eco Module 1:*** *thermoplastic PE based encapsulant; co-extruded PP backsheet; 3.2mm front glass*
  - ✓ ***PV Re² Eco Module 2:*** *thermoplastic PE based front encapsulant; co-extruded back encapsulant / backsheet based on PE and PP; 2mm front glass*
- **Functional unit: (production of) 1 Module (1.659 x 0.985 m)**
- **Silicon solar cell and Frame production (including upstream processes) dominate the environmental impacts of a PV Module**
- **Share of module production or the remaining module components (glass, cell connectors, polymers) significantly lower**

→ **First assessment: PV Re² contents are difficult to represent in the classic LCA or, in the worst case, negligible**

Life Cycle Assessment



- **Applied changes show a positive impact in all considered impact categories (e.g. global warming potential (GWP), acidification potential, eutrophication potential)**
  - ✓ *Relative improvement (in production phase) is rather small (2-3 %) due to no changes in the high impact areas*
  - ✓ *Positive effects on use phase (prolonged lifetime) and end of life phase (better recyclability and reparability) are not included in the assessment yet*



Framework:
Lifetime: *25 years*
Yearly Degradation: *0.8 %*
LCA (Lit.): *30 g CO_2 eq./kWh (southern European conditions*
Energy Output: *38.250 kWh/kWp (1.700 kWh/(kWp*a))*

Results:
GWP: *10 kg CO_2 eq./Module saved (= 30 kg/kWp)*
Savings: *0.78 g CO_2 eq./kWh (= 2.6 %)*

Summary and outlook

- **Development of a recycling friendly PV module design using thermoplastic polymers, lead free interconnection and detachable joints**
- **Positive impact on LCA, even though production of solar cells and frame dominate the environmental impacts**

Is it ecologically more friendly to repair or replace PV modules?

Is it ecologically more friendly to increase the service life or the recyclability of a PV module?

This research work was performed within the project "PV Re²" (Energy Research Programm -, FFG No. **867267**, Klima- und Energiefonds). The PCCL is funded by the Austrian Government and the State Governments of Styria and Upper Austria.