Cu-PV Project

Bart Geerligs, ECN Solar, Netherlands

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www.sustainablepv.eu/cu-pv

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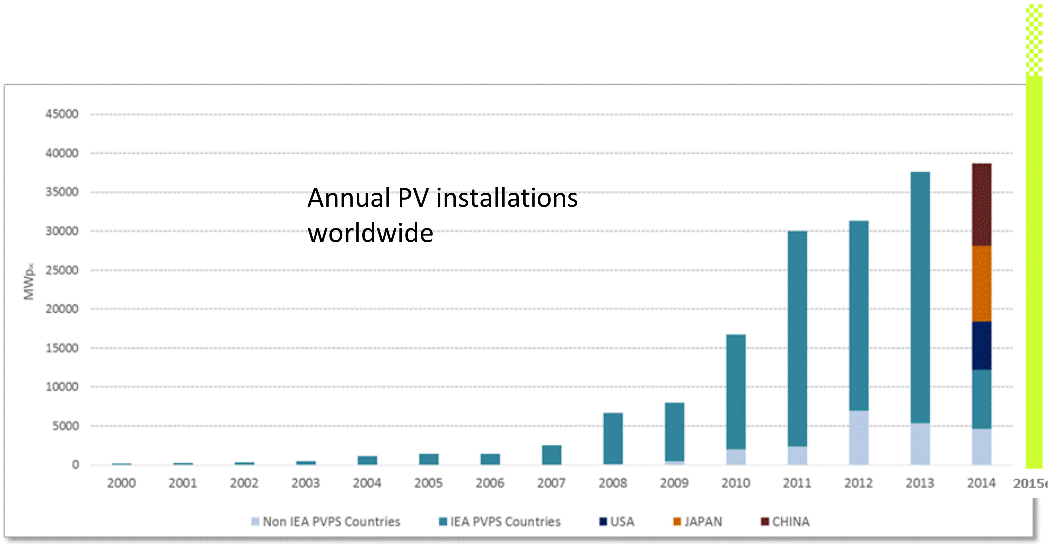
Introduction

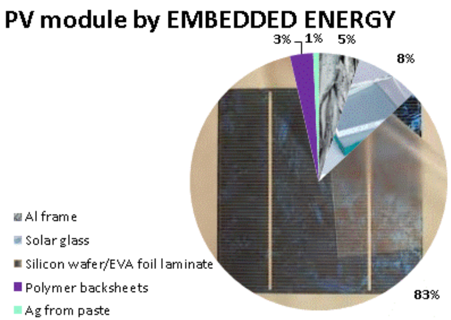
- Solar photovoltaics (PV) generation capacity grows quickly

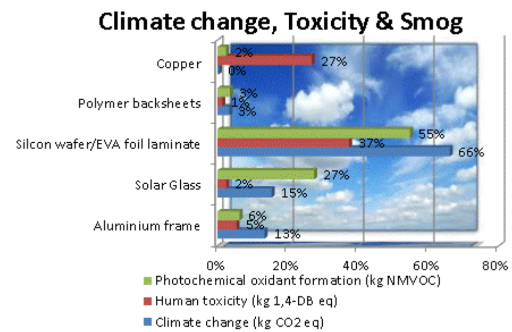


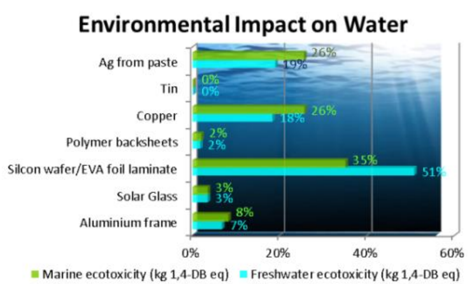
- Therefore the demand of PV on natural resources has to be minimized
- E.g., the carbon footprint of solar PV is not negligible, though much less than fossil fuel generated electricity (of order 40 g CO2-eq/kWh)

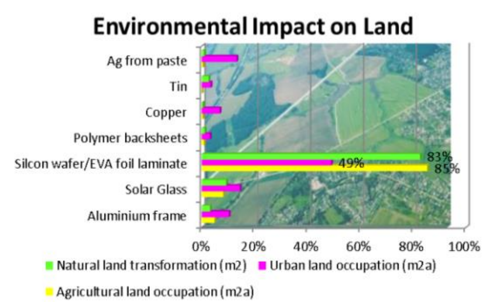
Sustainability of c-Si PV

- Key sustainability parameters of c-Si PV are:
  1. Energy for production of silicon wafer (cost, CO_2 footprint)
  2. Recyclability of PV modules (recovery of materials, CO_2 footprint)
  3. Use of Ag for metallisaton (cost, resource depletion)









C. Olson et al., EUPVSEC 2013

Cradle-to-cradle sustainable PV modules

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Sustainability of c-Si PV

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- To reduce environmental impact, Cu-PV project combined efforts on:
  1. Very thin, high performance solar cells
  2. Module technology designed for recycling
  3. Reduction of Ag consumption for solar cell metallisation

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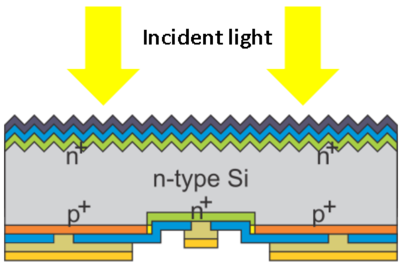
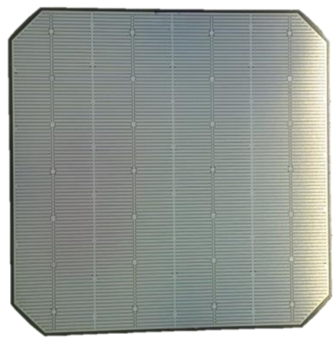
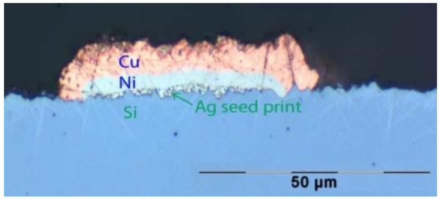
Cu-PV solar cell development

- ultrathin back-contact solar cells of 21-22% efficiency







Cell type	Ag-reduction	Thickness	cell efficiency [%]
Standard industrial cell (ref. ITRPV)	- (2010: 300mg; 2014: 130mg)	160 µm	18-20%
Cu-PV cell with evaporated seed layer and Cu plating (Ag-free)	0mg	135 µm	21.5
Cu-PV cell with printed Ag seed layer and NiCu plating (in progress)	70-94% reduction (ref. 300-450mg)	120 µm	20.2

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Benefit from thin high-performance cells

Carbon footprint

- CFP for thin cells of 22% cell efficiency is ~15-20% lower than standard cell of 18-20% efficiency

Ag resource savings

- at annual production of 100 GWp, every 100mg Ag per cell avoided means 2000 ton/y Ag savings, or ~10% of annual world primary Ag production

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Exploitation solar cell technology

- Meco/Besi
  - major supplier of plating equipment for PV

  exploitable results relate to:
  - high yield on thin wafers
  - plate on seed, particular printed seed
  - OSP capping, single side plating, etc.

- Xjet
  - developing inkjet metallisation for solar cells since 2007
  - collaboration with several major PV manufacturers, including industrial beta-tools
  - after promising start in Cu-PV, in 2014 due to solar equipment market conditions, board decided to stop solar and focus on 3D printing
  - Xjet is willing to support exploitation by other interested parties
- Institutes (ECN, Imec)
  - technology transfer, contract work, joint further development
  - high-efficiency cell technology jointly marketed with process equipment manufacturers

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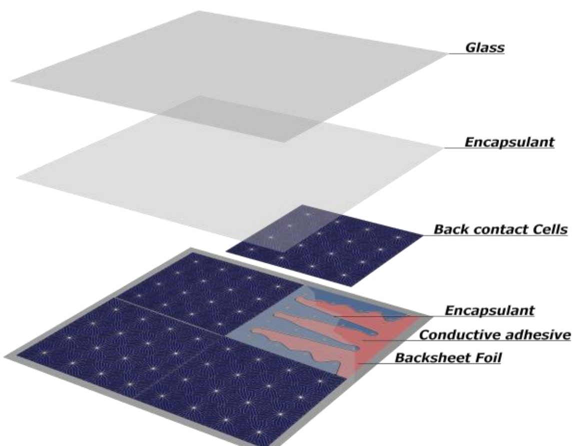
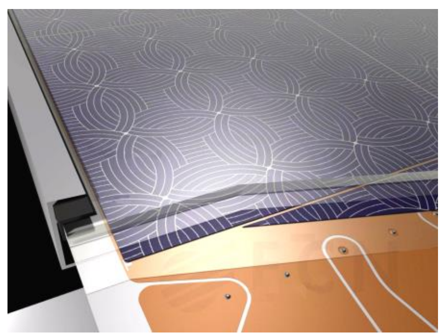
Cu-PV module development

- thin back-contact cells require dedicated module technology
- Backfoil based module technology was improved for application to IBC, cost reduction, and lower environmental impact of backfoil
- Backfoil based module technology was augmented with design for recycling:
  - framing and edge sealing
  - encapsulant





2x2 IBC module
(60-cell module planned Sept 2015)

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State-of-the-art Si PV recycling

Collection damaged/end-of-life PV modules

↓

Removal J-box → electronic waste

↓

Removal aluminium frame → aluminium smelters

↓

Hammer mill remaining laminate (glass – EVA – solar cell – EVA – backsheet (Fluor)

↳

- clean glass → packaging industry
- contaminated glass → glass wool industry
- metal tabbing → metal industry
- "fluff" (EVA-solar cell-backsheet) → stored in big bags or is disposed off

- Disadvantage: value reduction and loss of valuable material

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Why improving recyclability Si PV modules

- Enable cheaper, more cost effective recycling process
- Maximize amount of separated high value material
- Reduce depletion of scarce and expensive resources by increasing re-use
- Reduce carbon footprint of PV modules

	decrease in EPT (%)	decrease in CFP (%)
Al-frame (etch and anodise)	~3	~5
Glass (option 1 = remelting)	~2	~2
Glass (option 2 =direct re-use)	~4	~3
Wafers (option 1 = feedstock)	~30	~26
Wafers (option 2 = direct re-use)	~77	~72

EPT = energy payback time

CFP = carbon footprint

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Module recycling

- Technical Plating has developed process and semi-automated line for recycling of currently collected waste PV modules
- separating junction box, aluminium frame, backsheet
- capable of recovering clean unbroken glass sheets
- evaluating recovery of silicon, Ag, encapsulant
- Ag recovery from cell fragments evaluated with noble metal recyclers >> business case appears to be present

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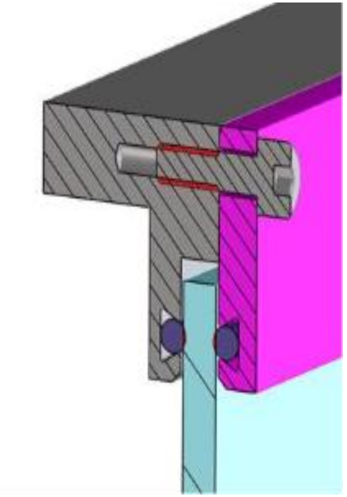
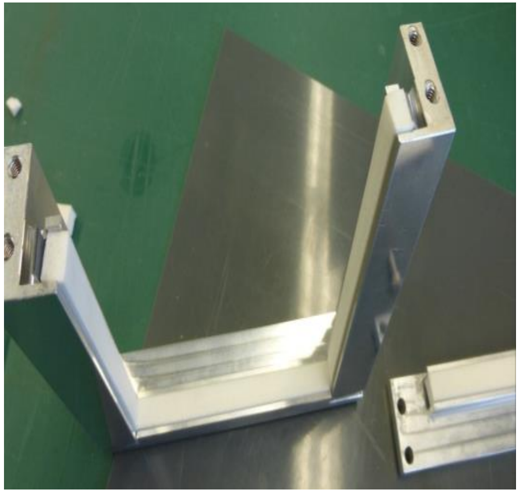
Design for recycling applied to module frame

- Module edge sealing was modified, maintaining reliability but improving detachment of frame
- Examples for which improved performance in accelerated degradation tests was demonstrated:





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Design for recycling applied to laminate

- Encapsulant can be changed from EVA to thermoplastics, maintaining reliability but allowing recovery of intact cells
- Reliability of modules with (Cu-plated) cells laminated with thermoplastics was demonstrated
- Methods to recover intact wafers were developed

Glass with thermoplastic (mechanical cleaning)

undamaged solar cell (clean by incineration)

Back-contact foil (Cu-PET-PVF) (cleaning under development)

- Glass and solar cell, recovered and recycled, can contribute upto 29% in reduction of carbon footprint.

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Environmental benefits from recycling

- Summary of estimates of maximum decrease of EPT of a module, and CFP of kWh generated by PV, for various Cu-PV recycling/re-use scenarios (see D5.4)

	decrease in EPT (%)	decrease in CFP (%)
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Exploitation module and recycling technology

- Eurotron
  - major supplier for module production equipment for PV

  exploitable results:
  - integrated backsheet production system
  - high accuracy IBC cell placement
  - modules with design-for-recycling features
  - recycling know-how

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  recycling process
  - enhanced recovery of higher value glass, backsheet, frames
  - potential recovery of silicon, silver
  - automation
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  - IBC module technology
  - design for recycling, and subsequent recycling technology

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Conclusions

- Cu-PV has demonstrated large reduction of carbon footprint by moving to higher performance and thinner cells
- Large reduction of Ag consumption by modified cell metallisation
- Methods to improve recyclability and recovery of valuable materials from Si PV modules
- Recycling business cases need to be established more firmly
  - Stability and volumes of recycled materials are some of the issues

Which possibilities are there to stimulate manufacturers worldwide to adopt features for more advanced recycling?

- Policies?
- Environmental Footprint Labeling?
- Other?

Extra slides

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c-Si PV lifecycle (part 1)

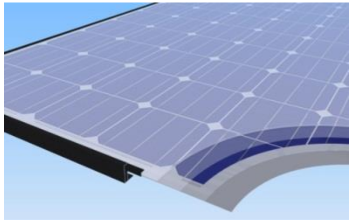
production high-purity Si ⇨ crystal growth ⇨ cutting wafers ⇨ cell production ⇨

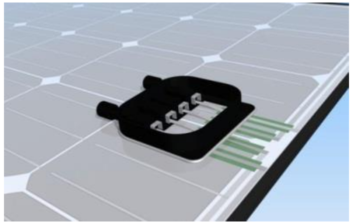
≈26% of CFP

46% of CFP

soldering into strings ⇨

laminate between backsheet and glass ⇨





edge sealing, frame and junction box

≈14% of CFP
(glass ≈3%)

≈7% of CFP

Note: CFP numbers are approximate, for monocrystalline cSi modules

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c-Si PV lifecycle (part 2)

end of life modules

recovery Al frame and junction box

shredding

recovery copper

recovery glass cullet

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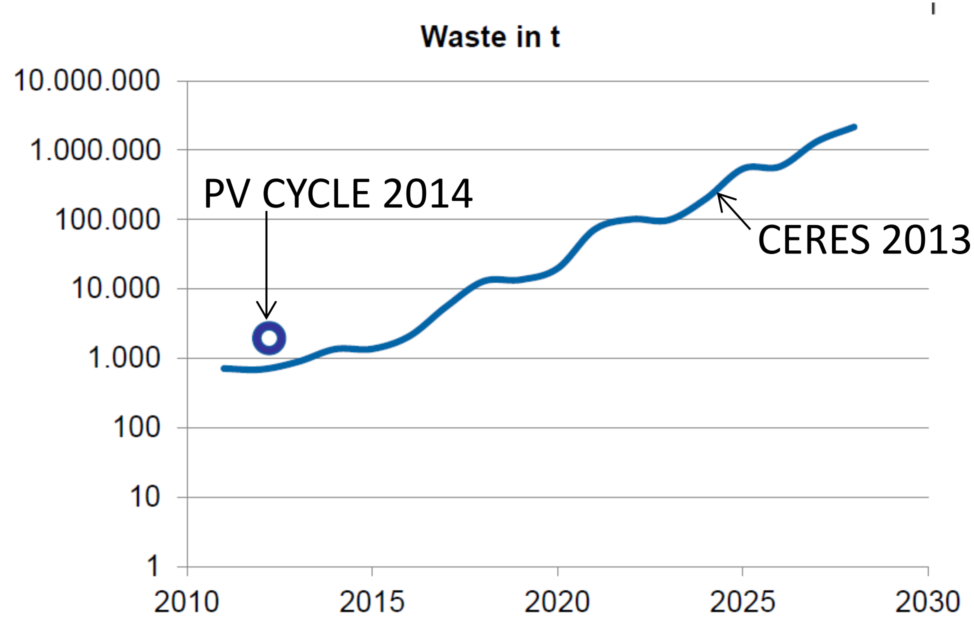
Forecast mass of end-of-life modules



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Growth of PV

LowE Glass– Float Plant

Produces 300-1000 tons of glass per day
– Uses 60-200 tons of recycled cullet

Major PV manufacturer

1 - 2 GWp per year
– Uses 300-600 tons glass per day

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ITR PV and Cu-PV cell type

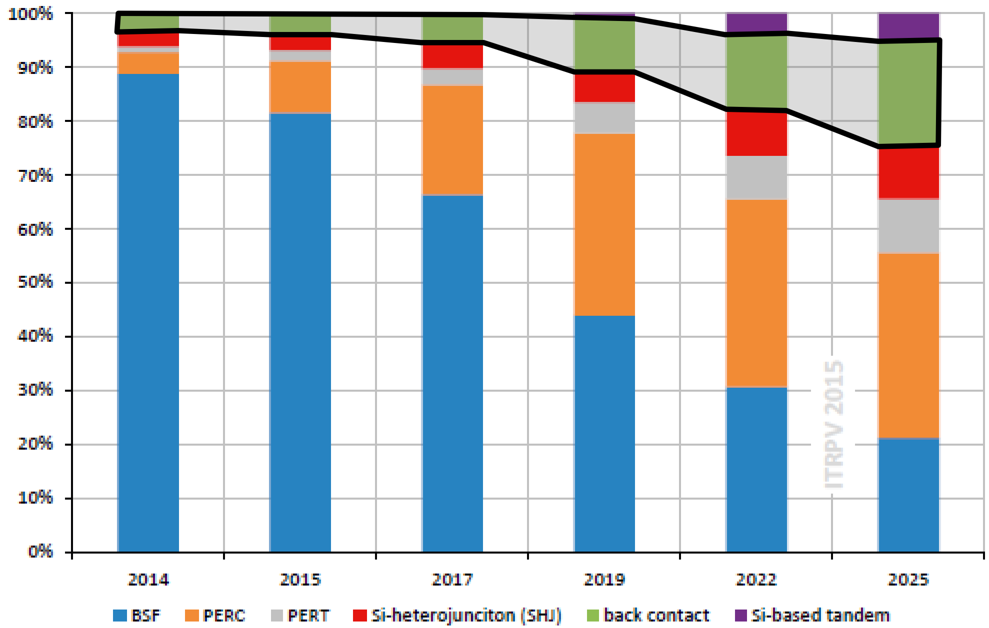

Fig. 28
Worldwide market shares for different cell technologies.

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