

Topics Market Place

Topic 1: New interconnection technologies: a recipe for disaster in 10 years?

Can shingling, paving, tiling and other zero-gap technologies combine performance and the necessary reliability?

Topic 2: Are ECAs the way to go to solve all problems?

Lead-free, low temperature, textured ribbons,... Is there something they cannot do?

Topic 3: Is Cu finally ripe for the big show?

Can Cu plating and/or Cu pastes solve our Ag problem?

Topic 4: Printing at the Terawatt scale: what will it look like?

Will screen printing crank up its game as it has always done, or has the time come for a truly new technology?

Discussions led by 2 moderators for each topic

Wrap-up on Tuesday morning by moderators

Topic 1: New interconnection technologies: a recipe for disaster in 10 years?



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Topic 1: New interconnection technologies: a recipe for disaster in 10 years? Maybe even 5 (Failing backsheet story...)

Can shingling, paving, tiling and other zero-gap technologies combine performance and the necessary reliability?

- Paving, tiling zero gap
 - Round wire has higher mechanical yield than flat busbar, more rigid
 - Cost of round wires manufacturing probably higher than flat busbars
 - Round wire + zero gap = killer -> need flattening of wires but flattening process might impact the stability of the wire
 - Reliability might have been reduced already with introduction of round wires!
 - Price of EVA 250% in one year -> going in the opposite direction
 - 400um wire allowing 450um encapsulant, not less
 - Optical width of round wires might not be significantly better than flat
 - Management of round wires in machine more critical than flat (downholding)
 - 0.5-0.6mm x 0.2mm flat ribbons might be the solution
 - Everything will be even worse with large size modules (example mech load)
 - Higher power vs higher efficiency: different approaches required (rooftop vs utility)
 - REC patent on half cut module design might be enforced

Topic 1: New interconnection technologies: a recipe for disaster in 10 years?



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- Shingling
 - Edge passivation could make sense with Chinese ALD tools, needed for HJT cells
 - IP issues: is a module design patentable? Solaria apparently suing other companies
 - Alternative shingling processes in development: Foilmet connection, matrix
 - Cu based ECA could reinforce value proposition -> need to demonstrate reliability
- Sustainability and Logistics
 - Will RoHS be ever applied in CHN? Who will pay the difference?
 - Sustainability of our industry getting increased interest...recyclability
 - Logistic issues with module size vs container size
- Tandem? After the first disaster (>10 years)

Topic 2 : Are ECAs the way to go to solve all problems?

Lead-free, low temperature, textured ribbons,... Is there something they cannot do?

- Good way to be Lead-free
 - Good reliability due to ductility and less stress induced by the low temperature curing
 - Compatibility with tandem SHJ-Perovskites
 - Only if short curing efficient at very low temperature
 - Higher Wp using textured ribbons

 - **But Cost?** compared to the soldering interconnection, especially MBB.
 - Full line ECA not competitive but ECA pads reliable enough. **Alternative Fillers**
 - Compatible with thin cells
 - **High cost of the Textured Ag coated ribbons**
 - => **New ECA with low filler content required for ribbons without noble coating**
 - **Limitation of the quantity of ribbons** because higher ECA deposit and because narrow ribbons more expansive => means long fingers => **means (for the cell metallization) the impossibility to decrease the Ag paste deposit**
- Glueing of wires?** Is it **reliable** with a **limited amount of ECA?** **Cost?** => thick & narrow ECA pads mandatory
=> **high stringer accuracy required**
- ECA with **shingle**. **Is it cost competitive?** due to cell cost (fingers length: 1/6 tiles equivalent to BB3) **Cu pastes**

Topic 2 : Are ECAs the way to go to solve all problems?

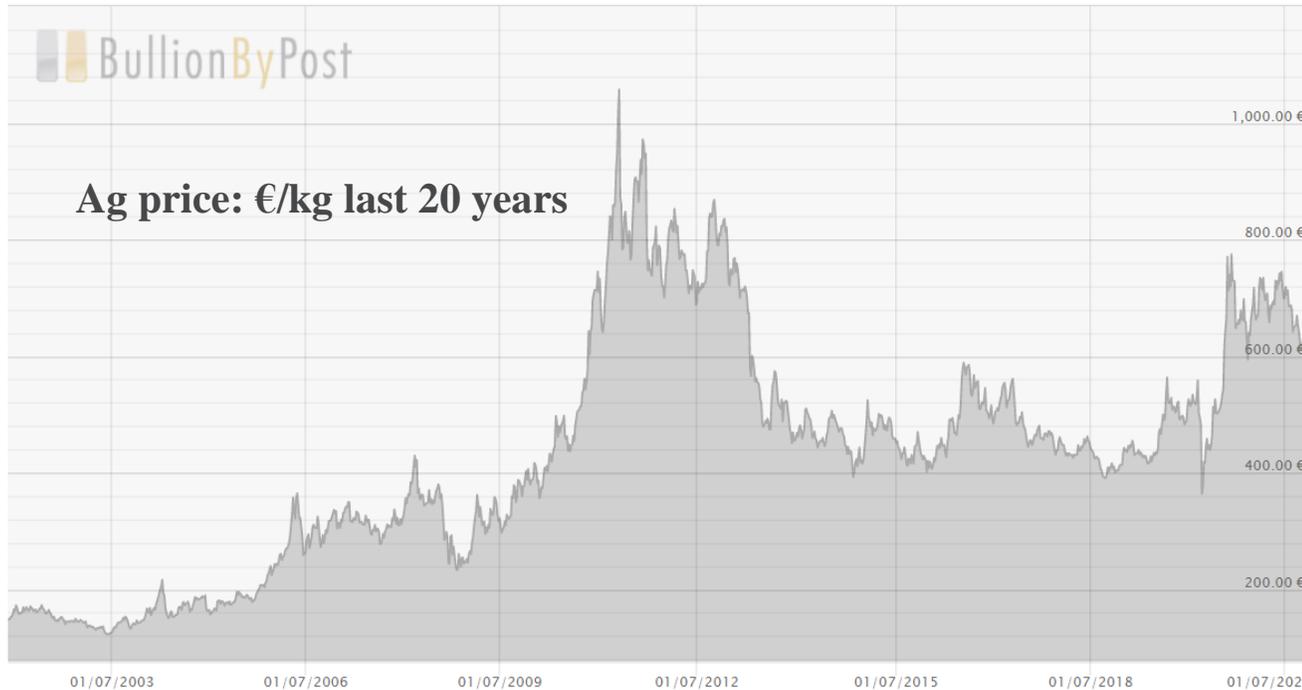
Summary

- ECA is definitely a key technology for the actual SHJ cell technology interconnection and shingle module manufacturing; reliability/ sustainability (Pb-Free/low temp.) / application are well demonstrated:
- Few factors needs to be addressed
 - Accuracy/precision placing wire-bb; in particular referring to round wire →machine manufactory
 - Contacting tin-lead ribbon and/or Cu ribbon as a part of the cost saving strategy
 - Processing of the next gen solar-cell as for tandem and Perovskite →needs for low temperature curing < 130C / fast curing <10s

ECA material manufactory need to chatch up the momentum and prove the scalability of the technology

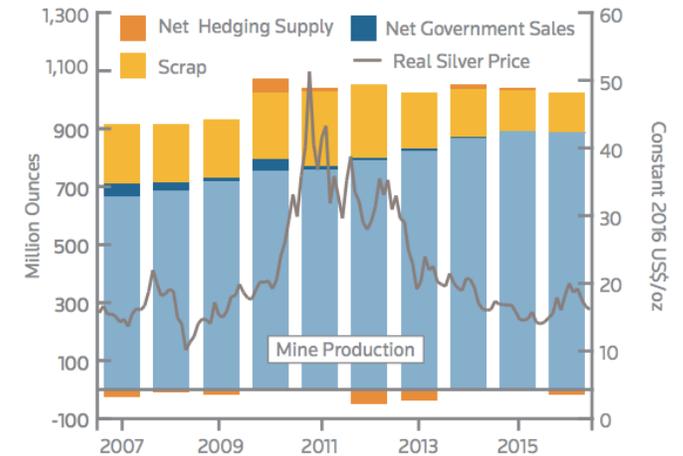
Topic 3: Is Cu finally ripe for the big show?

- From Cu plating and Cu pastes which one will be the solution to our Ag problem.



Ag availability is limited by production facility.

WORLD SILVER SUPPLY



Source: GFMS, Thomson Reuters

Ag mine production: 25'000 metric tons/y + 4'000 tons/y recycled [2]

100 mg Ag/cell of 6W

200 GW/y of PV = 3'3000 tons Ag/y (~12% of global Ag production)

1 TW → ~60% of Ag global production

Topic 3: Is Cu finally ripe for the big show?

- What is the limiting factors for the Cu plating technologies?
 - Will cells with Cu last 20 years in the field?
 - China regulation for plating due to old PCB, difficult to get licenses in some locations.
 - Conservative PV industry is making the implementation of Cu plating a very slow process.
 - Investment for plating compared to screen-printing is higher, so this could be a stopper.
 - No one is ready to make the large investment for Cu plating.

 - But MECO sold 20 pilot line the last 10 years, industry is getting prepared the way out of Ag.
 - MECO 300 MW or doubling the capacity, 4 in in the line for the plating. Lifetime of the solution in the bath: more than 2 years. Only need annually maintenance.
 - The price of silver will be the trigger for the change to Cu metallization! What is this price? No exact value proposed.

 - Which copper plating process will win?
 - Light induced plating is too slow
 - Electroless plating is also too slow and more difficult to control
 - Copper electroplating on the seed layer (bifacial) is the way to go!
-

Topic 3: Is Cu finally ripe for the big show?



- Cu plating and Cu pastes fight to be the solution to our Ag problem.
- Validation of these following points might make Cu-paste the next solution
 - Rheology need to be adapted.
 - How to make fire-through with Cu paste?
 - The cell need a barrier layer ? 10 nm of TCO is the good
 - Cell and module performance equivalent
 - Solderability of Cu paste
 - Reliability in modules
 - Price should be reduced compared to Ag. How much?
- Status of Cu Paste
 - Strong improvement during the last years: reduction of resistivity by 66%, price divided by 2. But more work need to be done!
 - Silver price is kept low, but it can increase very soon.

Topic 4: Printing at the Terawatt Scale



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Will screen printing crank up its game as it has always done, or has the time come for a truly new technology?

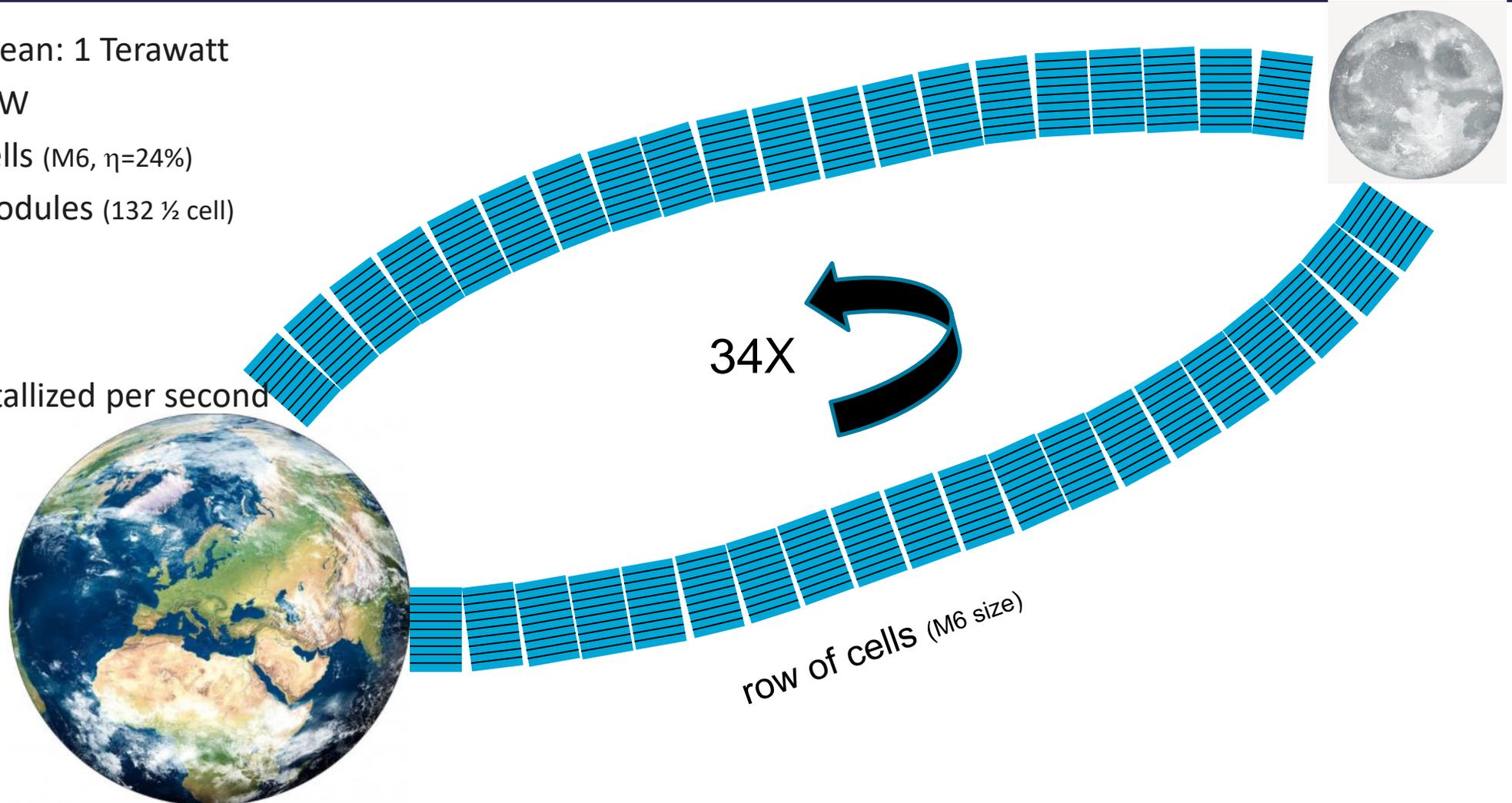
Topic 4: Printing at the Terawatt Scale

What does it really mean: 1 Terawatt

- 1.000.000.000.000 W
- 160.000.000.000 cells (M6, $\eta=24\%$)
- 2.400.000.000 modules (132 ½ cell)

AND

→ appx. 5200 cells metallized per second

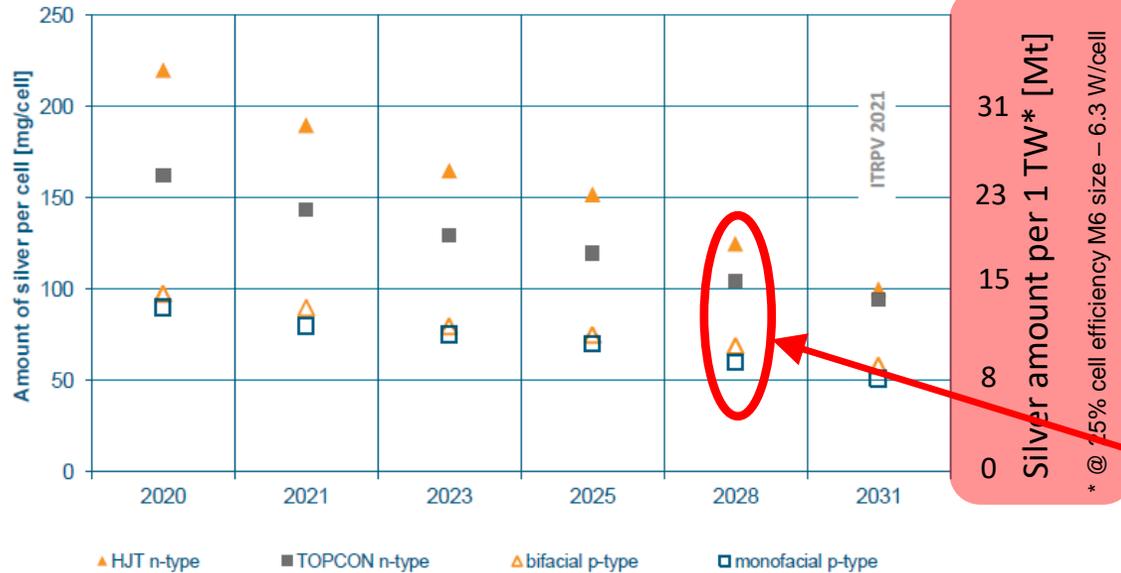


Printing at the Terawatt Scale – Ag issue



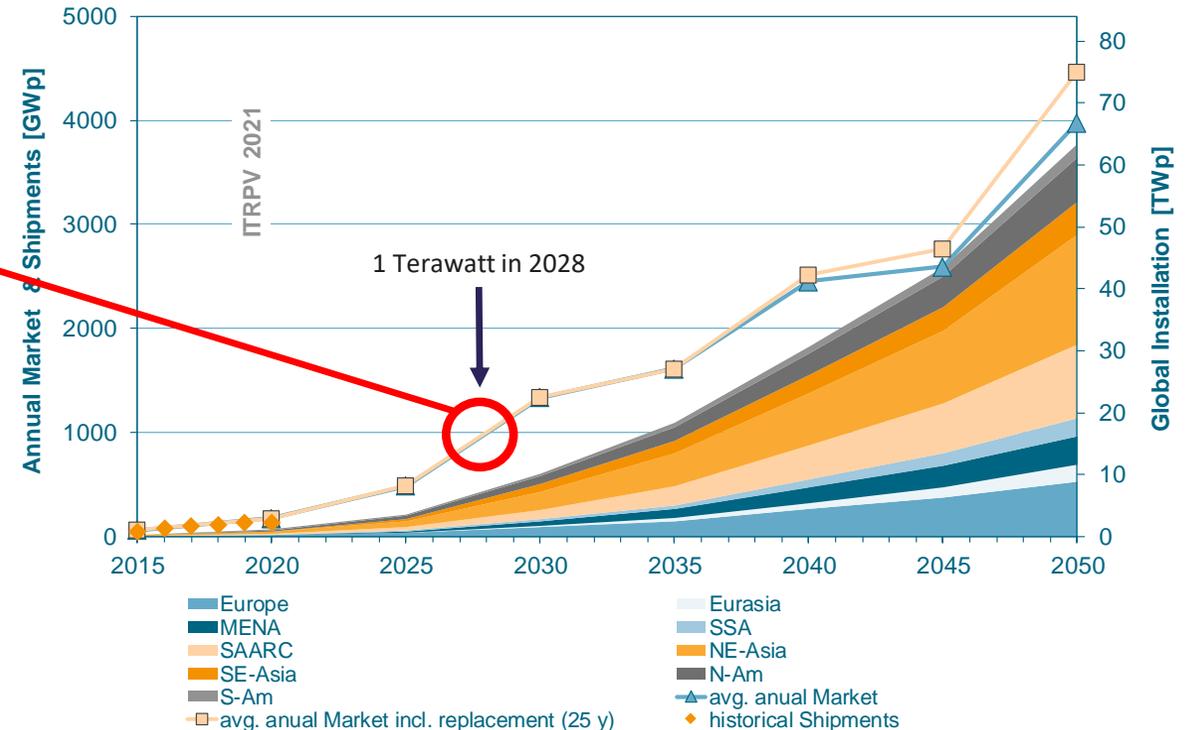
Trend for remaining silver for metallization per cell (front + rear side)

(Values for 166.0 x 166.0 mm² cell size)



Source: ITRPV; 12th Edition; April 2021

- 33Mt is the global Ag supply forecast for 2021**
- Thereof 10% for photovoltaics
- In 2028 10 to 20Mt required for 1 Terawatt PV
 → 30% to 60% of global supply required for PV



Source: ITRPV; 12th Edition; April 2021;
 Breyer ("Broad electrification")

**Source: Metal Focus

Printing at the Terawatt Scale



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- There is no urgent technological reason to replace screen printing
 - Efficiency: Screen printing will not limit cell efficiency potential for HJT, TopCon and Tandem
 - Floor space is not critical for screen printing technology even for Terawatt scale production
 - Throughput is not a strong driver to switch to another technology
 - Still a lot of room for improvement in FSP, esp. in terms of screen optimization
 - No supply issue for screen technology (mesh, emulsion, tools)

Printing at the Terawatt Scale



- Ag paste: Ag demand will become critical within the next decade
 - Strong silver reduction especially for HJT and TOPCon required, much faster than forecasted in the ITRPV Roadmap
 - Silver recycling necessary, but will not solve demand
 - (Partly) substitution of Ag necessary

- Alternative technology (e.g. Dispensing, Rotary printing, Plating, PTP):
 - Must be compatible with Ag demand reduction/ replacement
 - Needs to have a very low friction to switch to a new technology
 - Must have a high degree of automation
 - Needs to be a long term solution – No intrinsic limit to cell efficiency potential for HJT, TOPCon and Tandem

- It will be very challenging to overcome flatbed screen printing (and it will probably somehow overcome the Ag issue by itself)