OPTIMIZING FRONT AND REAR METALLIZATION GRIDS FOR BIFACIAL ANNUAL YIELD

Bas B. Van Aken[1], Santhosh Ramesh[1,2], Kees J.J. Tool[1], Jochen Loffler[1], Arthur Weeber[1,2], Gaby J.M. Janssen[1]

[1]: ECN.TNO, Solar Energy, Westerduinweg 3, 1755 LE Petten, The Netherlands
[2]: Photovoltaics Material and Device group, Delft University of Technology, 2628 CD Delft, The Netherlands
Corresponding author: bas.vanaken@tno.nl

ECN › TNO innovation for life

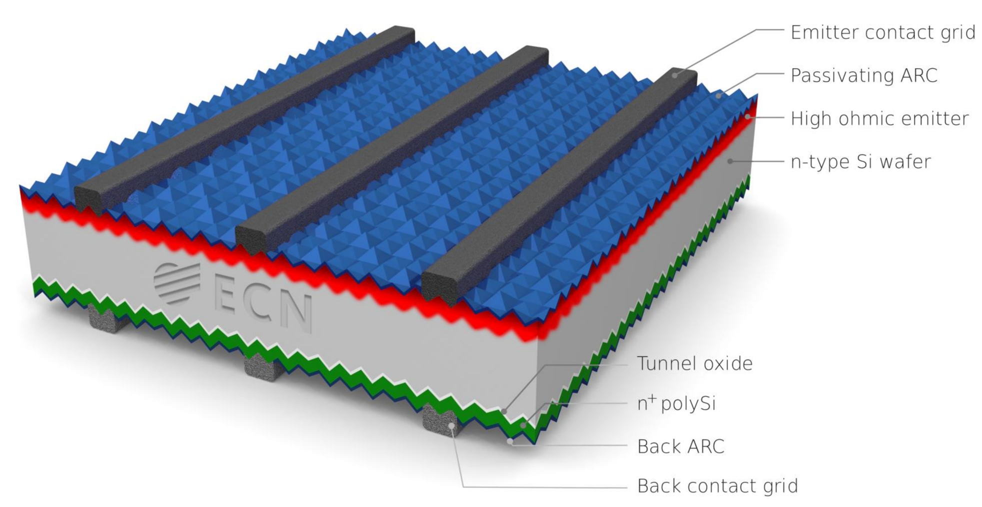
MOTIVATION

The metallization pattern determines the Ag consumption costs, but also influences the annual yield via the grid resistance and the shading losses. This work optimizes the bifacial energy output and the levelized cost of electricity (LCOE) by adapting the metallization pattern to several climate conditions

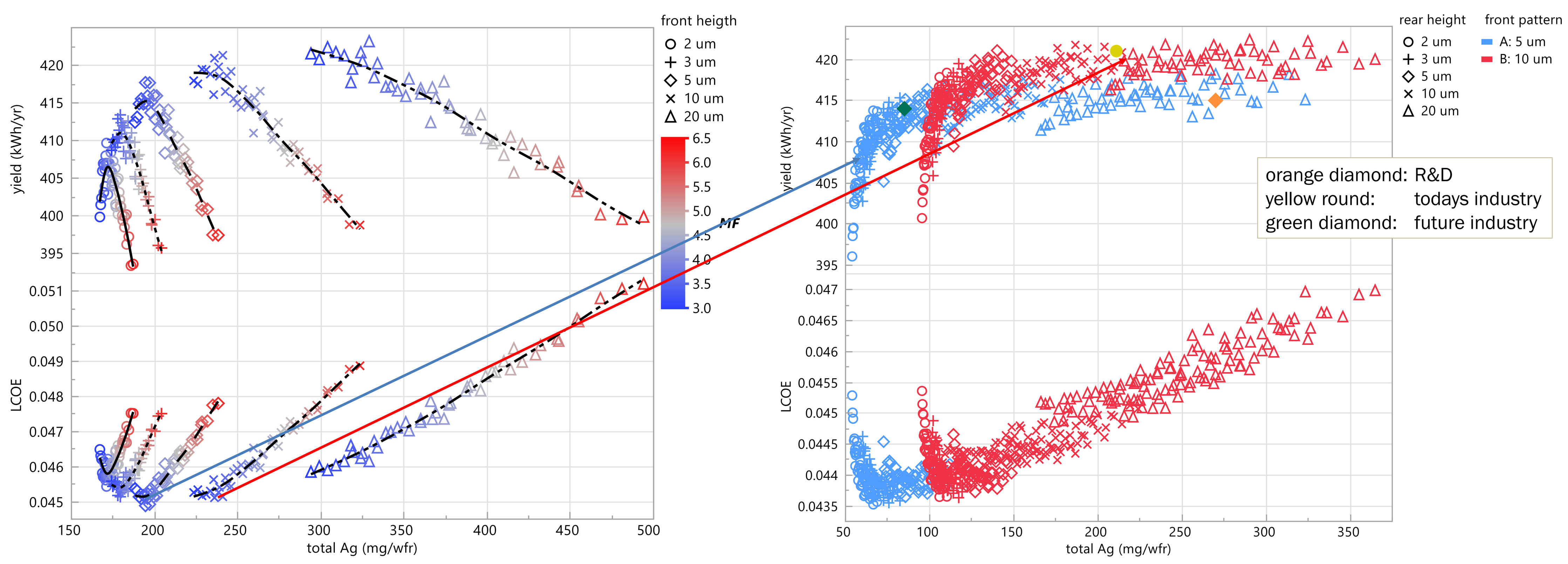
APPROACH

- Simulation the effect of metal pattern on performance of ECN.TNO's PERPoly (industrial TOPCon) cell using Quokka
  - varying grid pattern; first front with fixed rear, then rear with optimized front pattern
  - finger width and height and # fingers with known $J_{o,contact}$, $R_{contact}$ and R_{grid}
- Determining 60-cell module characteristics from Quokka cell characteristics, including bifaciality
- Estimating yearly yield using ECN.TNO.s BIGEYE simulation program for 3 different climatic conditions
  - maritime, continental and desert

ECN.TNO's industrial TOPCon (PERPoly)



FULL FACTORIAL FRONT (left) and REAR (right) METAL GRID VARIATION for MARITIME CONDITIONS



Front side first optimized with fixed rear pattern. Two front designs were selected for rear optimization: today's standard of 10 µm height and a reduced height of 5 µm (right graph B and A respectively)

Front side:

- Highest yield for highest metallization height: FF increases without decreasing Isc
- For high metal heights, lowest metal fraction (MF) gives lowest LCOE and highest yield
- for lowest metal height both LCOE and yield show an optimum at intermediate metal fraction

Rear side:

- Lower front metal height results in lowest overall LCOE.

CLIMATE EFFECT on YEARLY YIELD and LCOE

Metal height both front and rear is fixed at 5 µm (front pattern fixed at pattern A in the graph above). Lines are a guide to the eye only

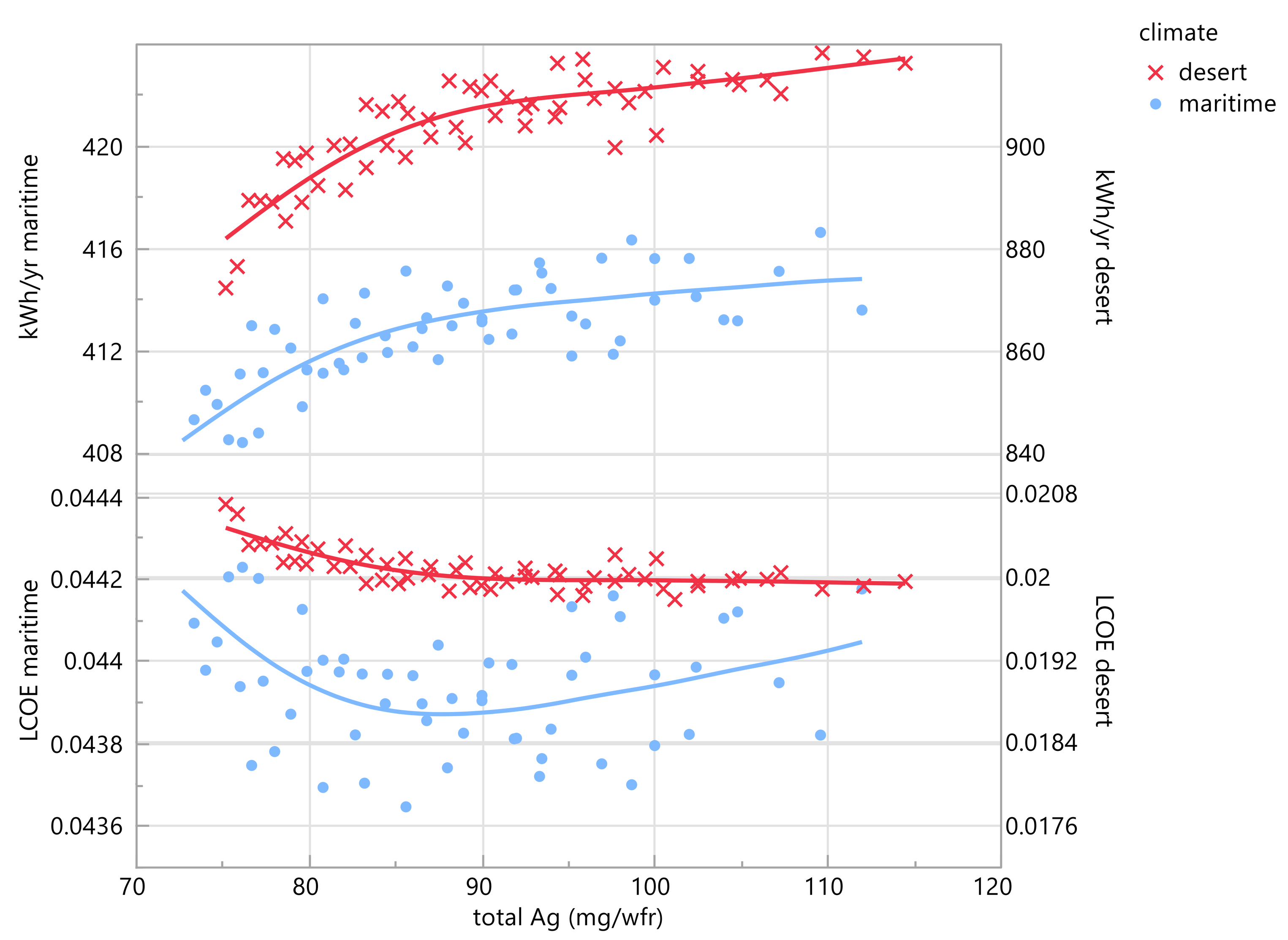
Desert conditions:

- Higher Ag consumption increases the yearly yield; lower series resistance results in less power loss at high currents. Curve flattens above ~90 mg Ag/wfr
- LCOE is nearly independent of the Ag consumption; the lower yield is compensated by the lower Ag cost. LCOE increases when reducing Ag/wfr below ~90 mg

Maritime conditions:

- The energy yield is less very sensitive to the Ag consumption. Only at the lowest Ag consumption a slight decrease of the yield is expected. Due to the relative low current the series resistance losses are not (yet) dominant.
- A minimum in the LCOE curve is observed at 80-90 mg is sensitive to the Ag consumption.

Note that although Ag height is the same for both climate conditions, the optimal front patterns used are not.



CONCLUSIONS

- High aspect ratio (high metal height) results in highest energy yield
- High aspect ratio for the metallization (high metal height) can be detrimental for the LCOE
  - 5 µm front metal height gives (close to) lowest LCOE for all 3 climate conditions evaluated
- Ag reduction of ~60% can be achieved without energy yield loss resulting in 3% LCOE reduction, even for the desert, high current conditions
- Optimized metal pattern for lowest LCOE depends on climatic conditions

Acknowledgements

- Polaris project executed with Topsector Energy subsidy of the Dutch Ministry of Economic Affairs
- ECN.TNO processing and characterization team for careful execution of the experiments