T-IPV: French contribution to IEA PVPS-T17

Back Contacts cells for VIPV applications: Opportunities & challenges

Bertrand CHAMBION, Fathia KAROUI, Nouha GAZBOUR, Fabrice CLAUDON

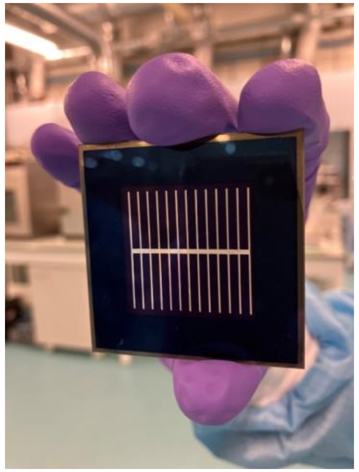
BC workshop, Delft, December, 5th

Contents

Introduction / VIPV context

- **VIPV = On board PV production coupled to vehicle energy need**

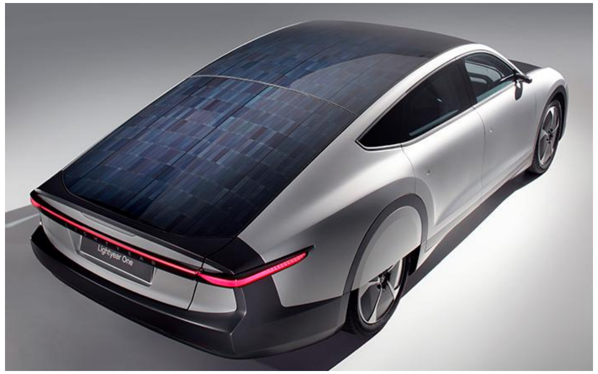
CEA Ines, 60µm Si-cell



CEA Ines, Tandem cell prototype

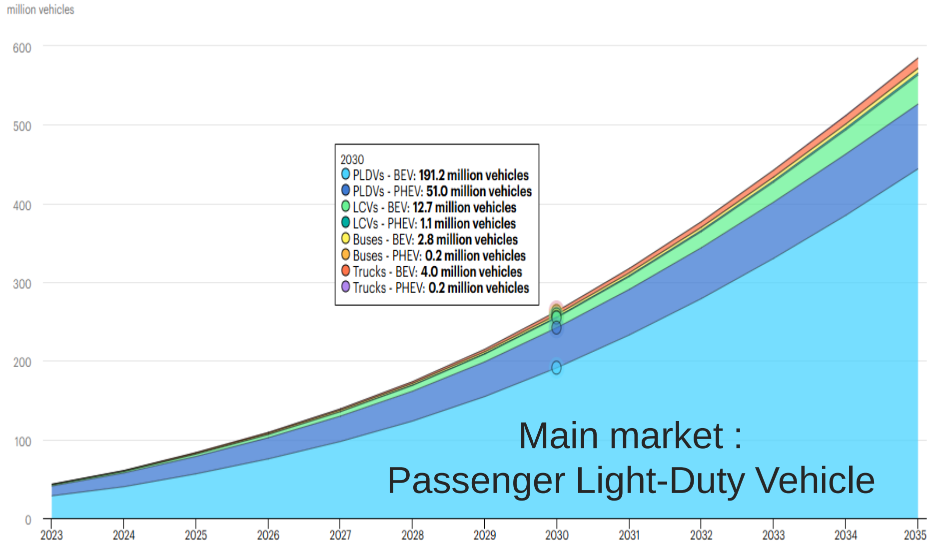
High performance cells
Flexible
>25%

VIPV



Lightyear 0, Maxeon website

IEA (2024), Electric vehicle stock by mode in the Announced Pledges Scenario, 2023-2035



➔ Logical combination of both technologies

VIPV module specs

PV Surface available ?

Vehicle integration, Challenges ?

Vehicle specifications ?

CEA Ines, Renault Zoe with solarization kit

Use case, V2X ?

Location ?

Annual solar km ?

LCA (eq. Kg CO_2) ?

End user benefits, ROI ?

VIPV performances estimation, modeling methodology

ENERGY

Inputs -Time series (Ghi)

Monthly solar energy

Distribution of solar irradiance

Use profile

Parameters

PV peak power
Battery nominal energy
System efficiency
Electrical consumption
Shading losses
Frequency of recharge with the grid

Mathematical model

Energy balance
Battery state of charge
} **15' steps**
Calculations for 365 days

Outputs

- Annual PV energy
- Annual mileage,
- Daily distance covered by VIPV
- Battery state of charge profiles

CIMATE CHANGE

Balance ($kgCO_2$-eq scenario)

=

Avoided impact

-

Manufacturing balance

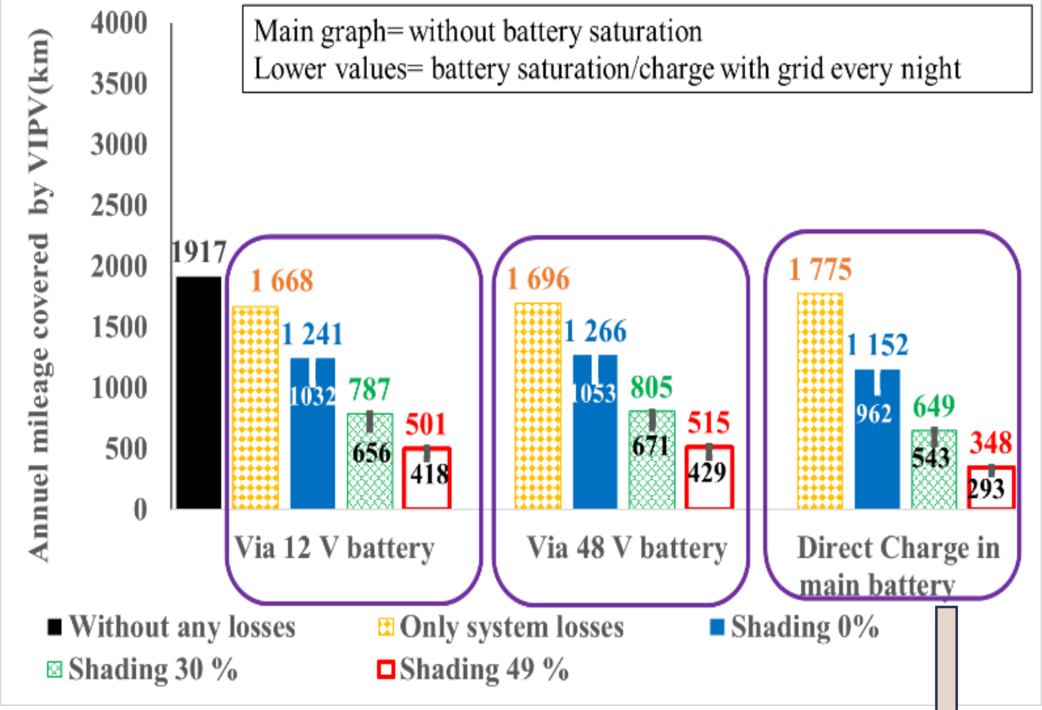
PV prod = avoided impact on the grid

Carbon balance manufacturing (x kg CO_2-eq)

Application on passenger car

- **Projections in 2030**
- **PV**: 1.44 m², 230 W/m²,
  - Ageing considered ➔**0.312 kW at midlife**
  - Curvature influence **:** - 8.8% Paris, -6.1% Malaga
- **Battery :** 50 kWh
- **Consumption :** 157 Wh/km

Paris, France (~average Europe): 293 - 805 km



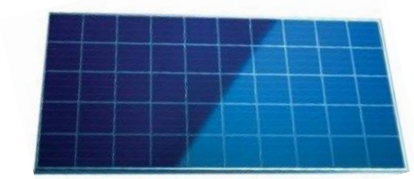
- **System efficiency and power thresholds for using PV**
- **Via 12 V auxiliary battery**
- **Via 48 V additional battery**
- **Direct charge in main 400V battery**
- **Use profile** : home/work (8am-6pm), 5 days per week, 48 weeks per year (12250 km/year)

- **Shading losses**: 0 %, 30 % and 49 %
- **Lifetime** :13 years

Optimized Realistic scenario, by 2030,
Paris : **650 km/year**
(Malaga:1350 km/year)

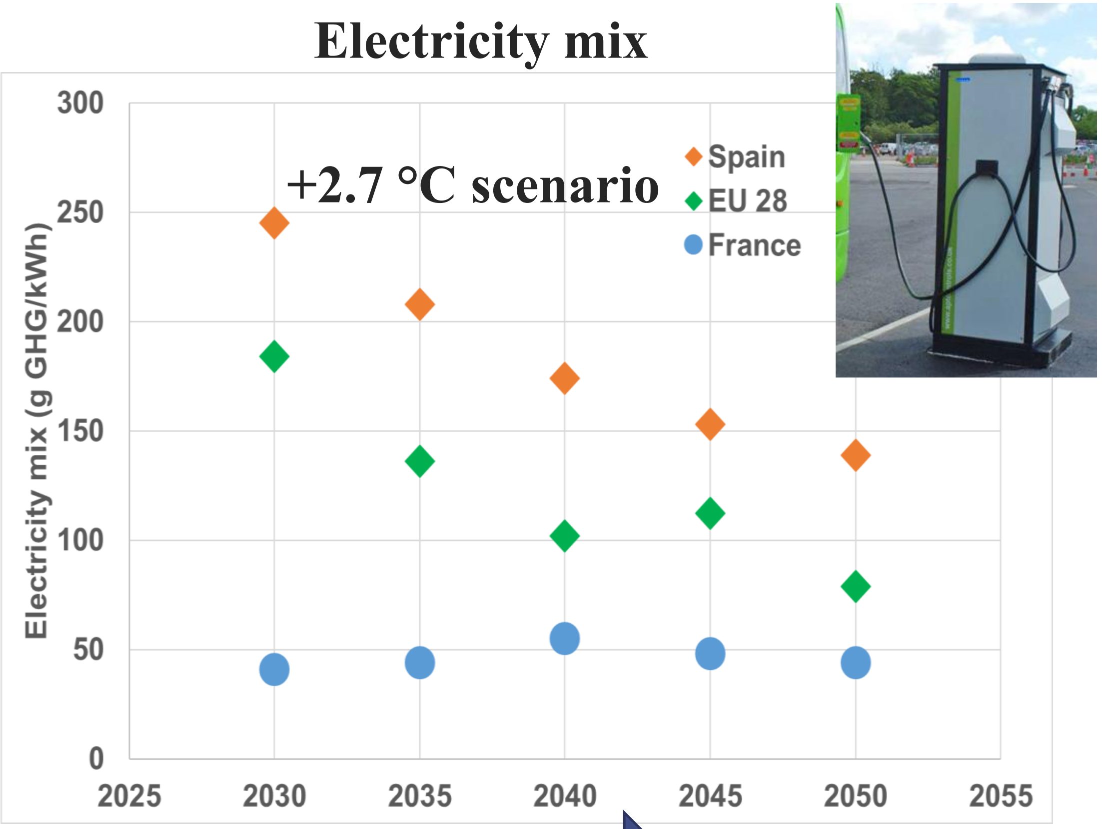
VIPV system key points

LCA projections and cells specs



- ✓ Technology: PERC+
- ✓ Poly silicon : Germany
- ✓ Lingot / wafer: Norway
- ✓ Module: France (GBS, no frame)
- ✓ Manufacturing: projection in 2030

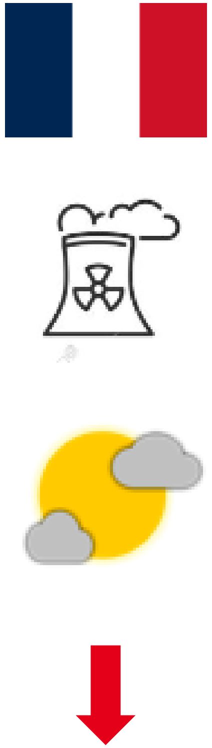
Low carbon



- ✓ Life time: 13 years / 160 000 km (commercialized in 2030)

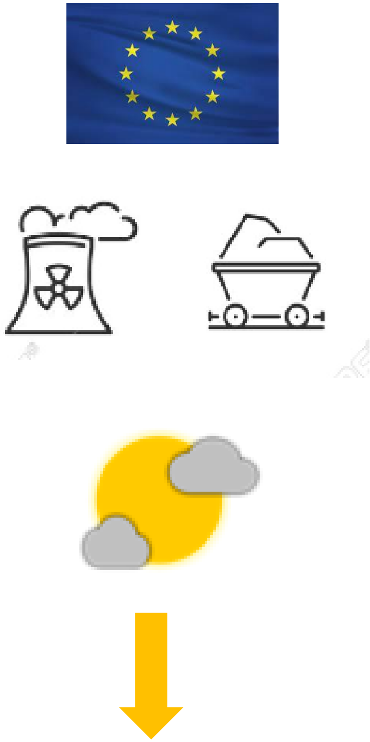
LCA projections on CO_2: Passenger car

FRANCE



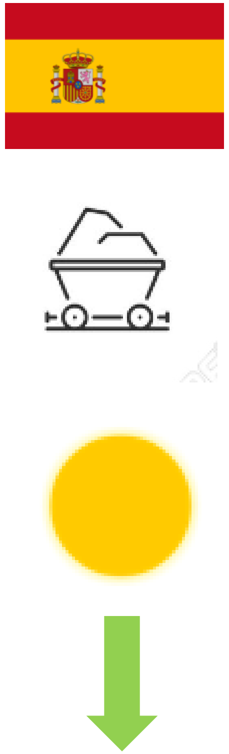
Paris : -102 to -2 kg CO2- eq

EUROPE



Average Europe : -39 to 122 kg CO2-eq avoided

SPAIN



190 – 489 kg CO2-eq avoided

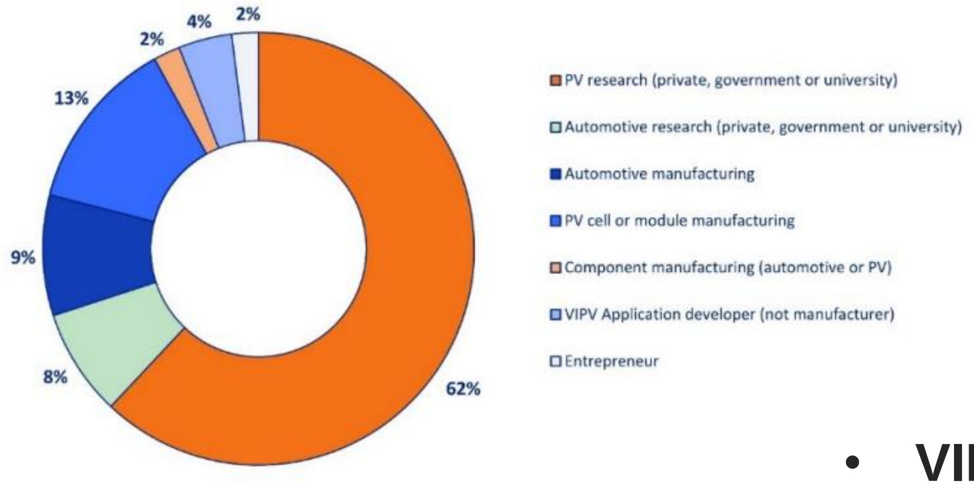
Initial passenger car footprint : 6-10 t CO2-eq

[https://doi.org/10.1016/j.rser.2022.112158]

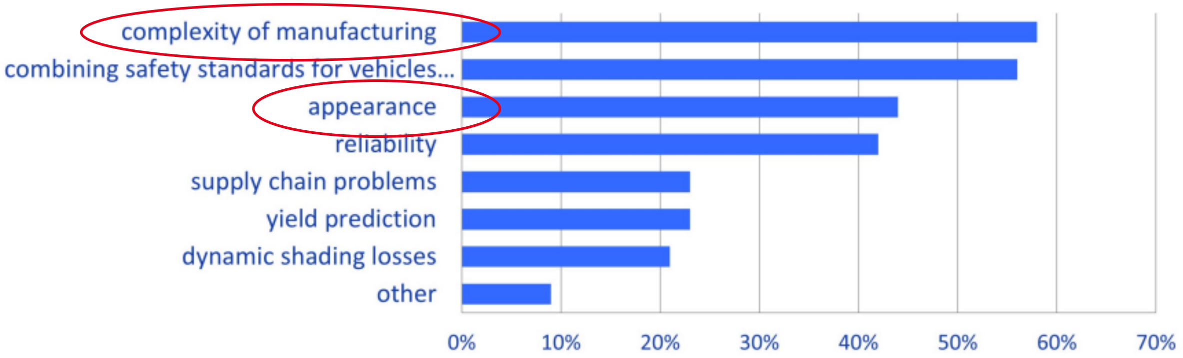
VIPV module specs

From technical survey leaded by TNO -Anna J. Carr and Bonna K. Newman – TNO, 2024 The Netherlands

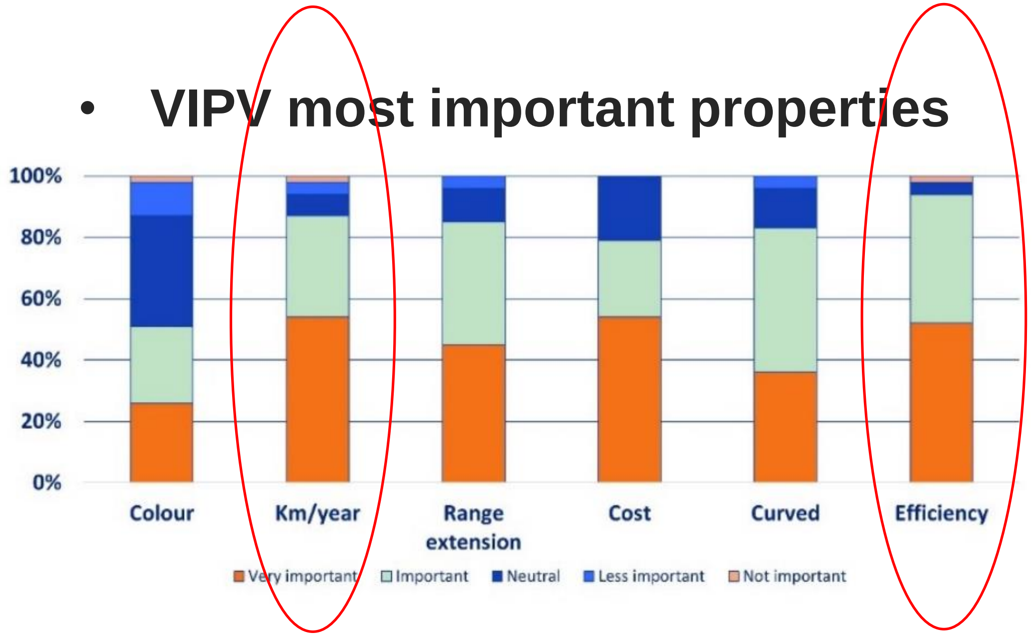
- 110 experts invited
  - 70 responses (64% response rate)
- Continents covered:
  - Asia
  - Europe
  - Australia
  - North America



- **Technical bottlenecks**



- **VIPV most important properties**



➔ **Main interests: efficiency, complexity of manufacturing, appearance**

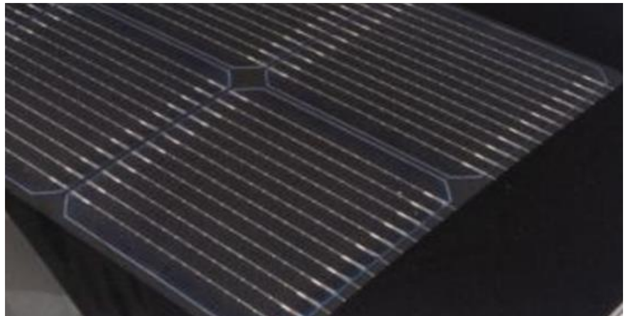
Back contact: aesthetic advantages

- Aesthetic for high efficiency modules

Lightyear, BC cells


Aptera, BC cells


Ioniq5, conventional cells


Visible wires

- BC can easily provide high efficiency module with black or deep blue appearance
- Conventional PV has to use black cover (= active surface losses + complex processes)

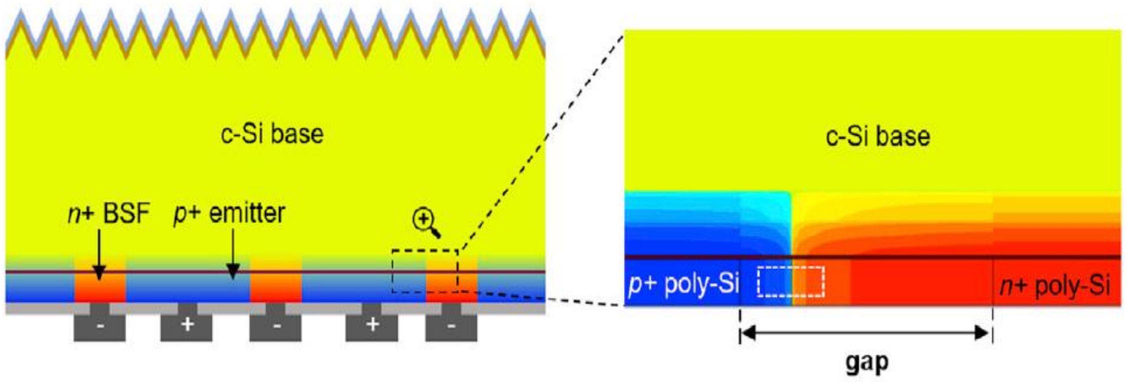

Fisker Karma

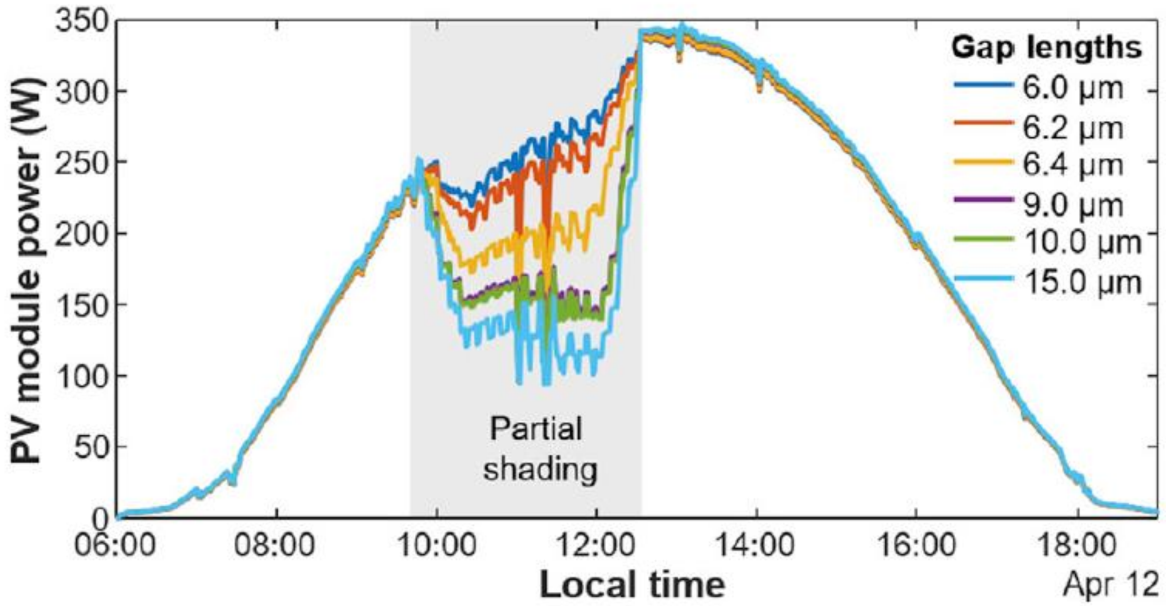
Back contacts: performances advantage

- **Metal free front side on BC cells**
  - Theoretical advantage to reach high efficiency cells ➔ key point for VIPV (cf system approach)

- **I(V) curve and reverse characteristics**

Calcabrini et al., Cell Reports Physical Science 3, 101155. December 21, 2022 ª 2022 The Author(s). https://doi.org/10.1016/j.xcrp.2022.101155





The wider the gap ➔ The best PV performances but low shading resilience
The smaller the gap ➔ The best shading resilience but lower PV performances

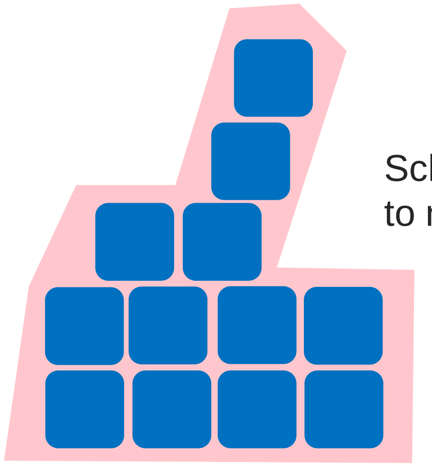
- **Benefits and safer under long term shading**
  ➔ next talk, SUPSI

EPJ Photovoltaics 15, 7 (2024) © E. Özkalay et al., Published by EDP Sciences, 2024 https://doi.org/10.1051/epjpv/202400

Towards adjustable shading performances on Cell?
➔ Use case oriented

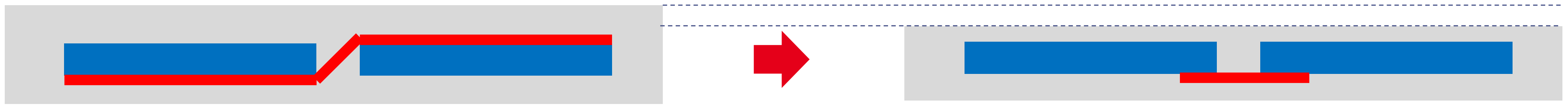
Back contacts: integration advantages

- **Easier layout on complex surfaces**
  - Electrical layout on cells back side, with conductive back sheet, films, ribbons, multi layers…
  - But : Needs of reliable BC interconnection
  - More complex in case of conventional interconnects



Schematic of specific layout to manage

- **Low profile string for thinner and lighter modules**



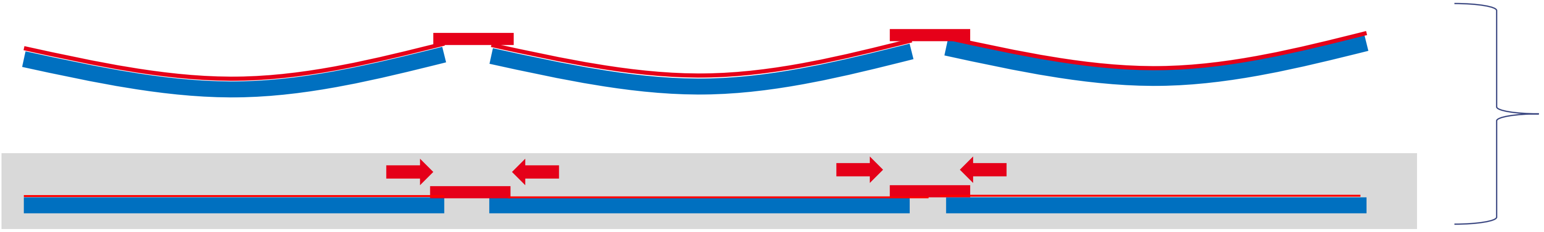
  - BC strings ~ 200µm thinner than conventional
  - Thinner front side encapsulation possible

Back contacts: **challenges**

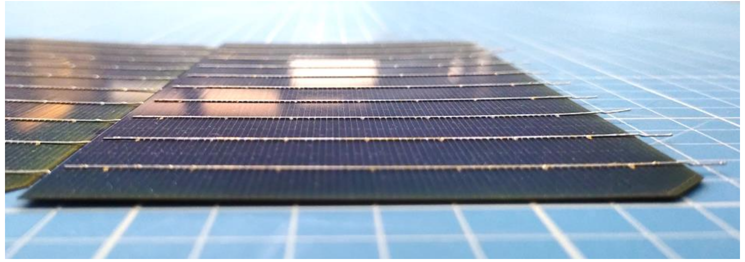
- **Metallic parts on one side**
  - Due to CTE mismatch (Cu-Si), Bowing effect on cell or strings
  - Could make processes more complex : dicing/ cutting, handling, P&P on curved surface
  - Could results in stresses on interconnects after lamination

BC cells string
before laminaiton

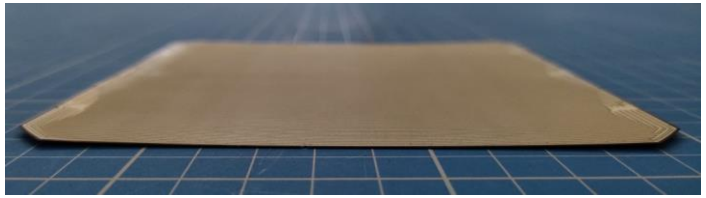
BC cells string
after lamination



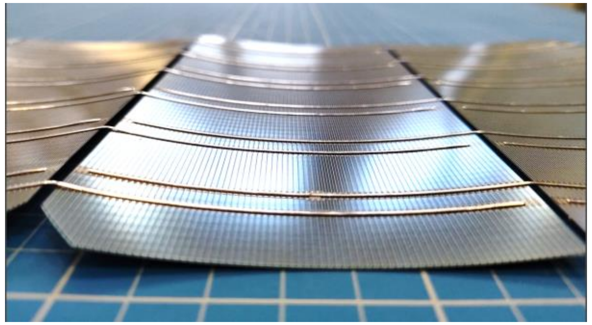
Compressive stress in
interconnects &
mechanical tolerancies
issues



Conventional vertical structure, MBB



BC technology 1



BC technology 2

Conclusions on BC cells for VIPV:

- Power density, good performance under partial shading
- Easy layout possibilities, aesthetic
- Low profile strings structure for lighter modules

- Cells bowing due to CTE mismatch
- Si thinning more complex
- String handling and bussing more complex
- Stresses on interconnects

Perspectives on VIPV / cells :

- VIPV is a complex system, not only PV parts
- No clear end user value (Energy and CO_2) for passenger cars

➔ Low carbon manufacturing process needed for cells
➔ BC bottom cells for tandem Si/PK is possible but a lot of challenges
➔ PK/PK seems to be the solution for CO_2 balance but reliability challenges

Thank you !

T-IPV: French contribution to IEA PVPS-T17

Back Contacts cells for VIPV applications: Opportunities & challenges

Bertrand CHAMBION, Fathia KAROUI, Nouha GAZBOUR, Fabrice CLAUDON

BC workshop, Delft, December, 5th

Contact : bertrand.chambion@cea.fr

BCworkshop2024