R&D SUPPORT FOR DEVELOPMENT OF BIPV PRODUCTS

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Outline

1. Introduction
2. R&D on material issues: mechanics, optics
3. R&D on electrical issues
4. R&D on overall energy issues: modelling and characterization of solutions
5. Conclusions

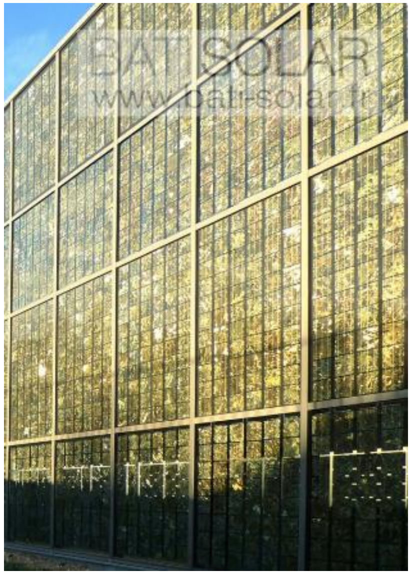
Introduction (1/3)

- **BIPV :**
  - Many definitions / very difficult to define
  - Many functions, therefore many products and types of installations
  - Many criteria, many requirements

- **The main criteria of integration in buildings (including some non-building structures) :**
  - Aesthetics
    - Colours (cells, backsheet, frames),
    - Planarity and shapes adapted to the envelope
    - Frame allowing no visible wiring
  - Additional functions
  - Economics : cost of installation
  - Certification (Durability, maintenance, lifetime)

Introduction (2/3)

- **BIPV solutions usually require :**



Conventional PV module

Slightly customized PV module, for instance :

- Specific frame
- Frameless
- With kit for integration
- With heat recovery on the backside

Fully re-designed PV module

Introduction (3/3)

As for any PV systems, R&D activities should aim to:

- **Decrease the LCOE (efficiency, lifetime, installation cost, etc.)**
- **Increase the value of PV electricity**

+ address BIPV specificities, which are critical to bring new design solutions :

- At the module level:
  - Size, color, shape, weight, flexibility
  - Functions
- At the system level:
  - Energy output optimization regarding overheating, shading and multiple orientations
- At the building level : optimization of the overall design
- Certification (energy performance, including reliability and lifetime)

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R& D on material issues :

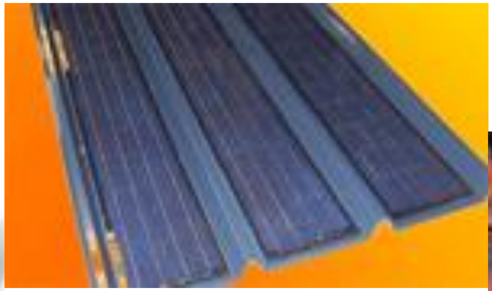
Material issues:

Mechanical parameters → Shapes, Weight, Strength, Flexibility, Conformability, Adhesion, Durability

Optical parameters → Colours, Texture Appearance

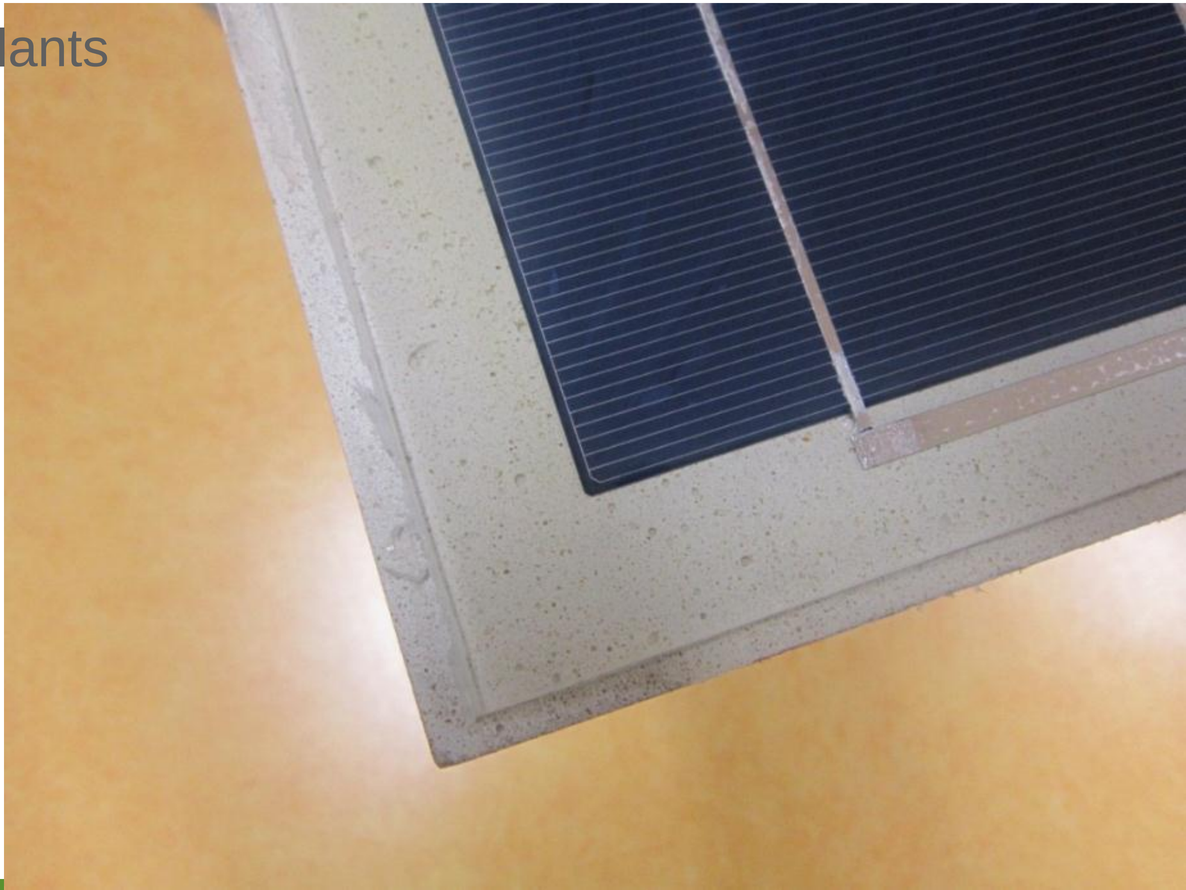
New processes for:

- **PV layer**
- **PV cell layout**
- **encapsulation**



Façade integration: Development of specific products with adhesives

- **PV modules directly laminated on prefabricated concrete structures (slabs, balconies) :**
  - with specific shapes
  - with specific encapsulants



Roof integration: refurbishment of industrial and commercial buildings with metallic structure:

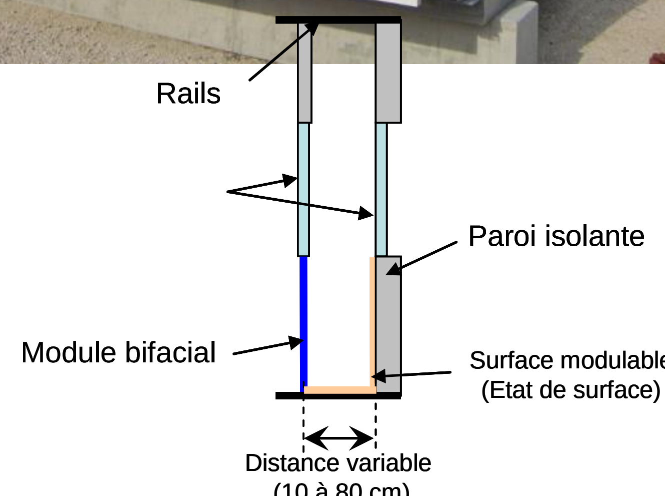
Requirements of lightweight modules:

- **< 2kg/m²**
- **> 120W_p/m²**

- **Very light modules can be also integrated on:**
  - electric planes Eraole
  - and balloons

Prefabricated façades with bifacial solar cells in a double skin structure:

- **Optimization of several parameters :**
  - Cell spacing
  - Distance between the two walls
  - Coatings of the reflective layers



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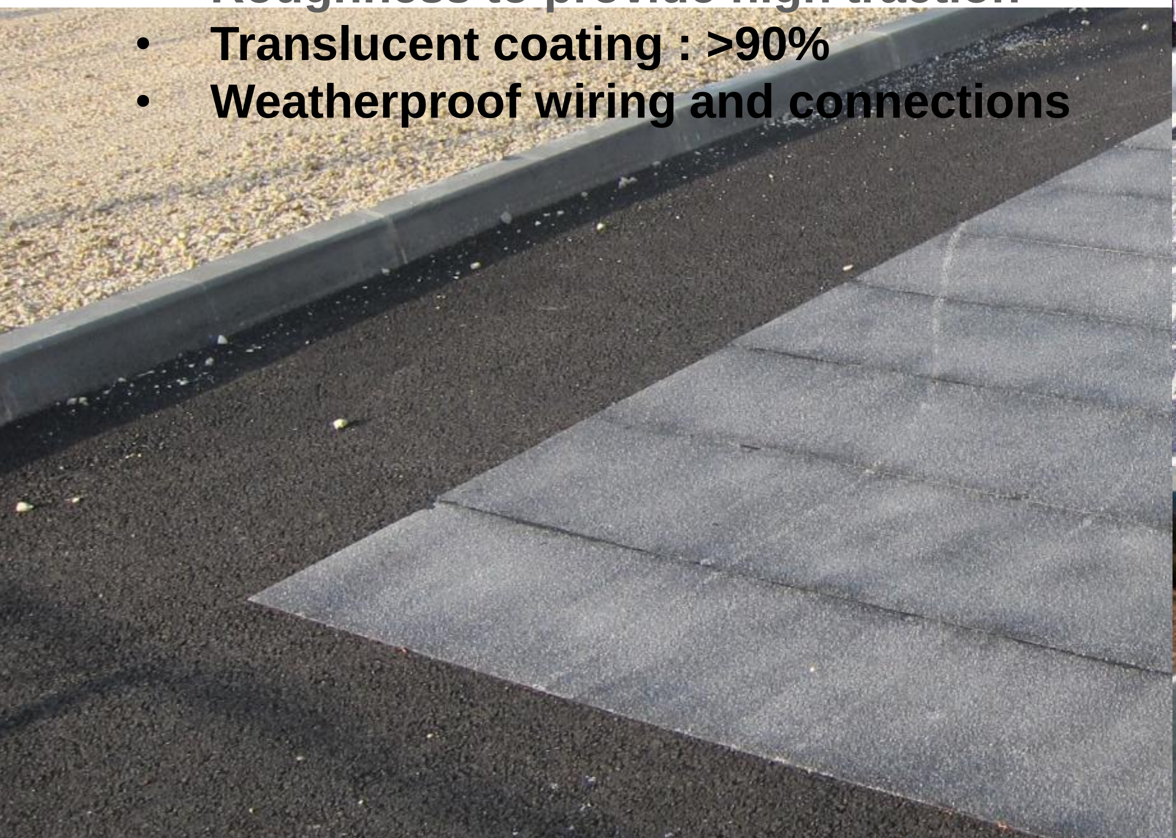
Beyond buildings, road applications:

- **Sidewalks, parking lots, streets, roads :**

- **Various criteria :**
  - **Heavy loads (trucks, stones, bricks, etc.)**
  - **Roughness to provide high traction**
  - **Translucent coating : >90%**
  - **Weatherproof wiring and connections**



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R&D on electrical issues :

Many issues during installation, operation and maintenance:

- **Easy connections and wiring**
- **Safety, arc detection**
- **Energy output optimization within a context of multiple orientations, shading, and temperature gradient: micro inverters, new inverter structures**
- **Fault detection and value optimization : increase of self-consumption through smart Energy Management Strategy, at the building level**

Decreasing installation cost with prefabricated components

- Easy wiring, using the domino concept: the electrical circuit is activated after installation, from the front surface, with specific connectors
- Power electronics may be integrated in the frame

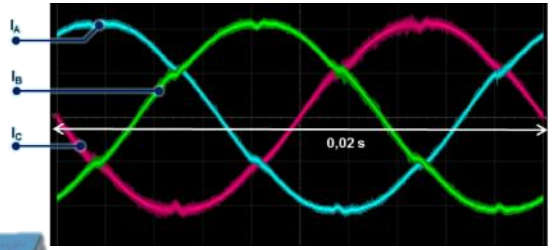
Safety

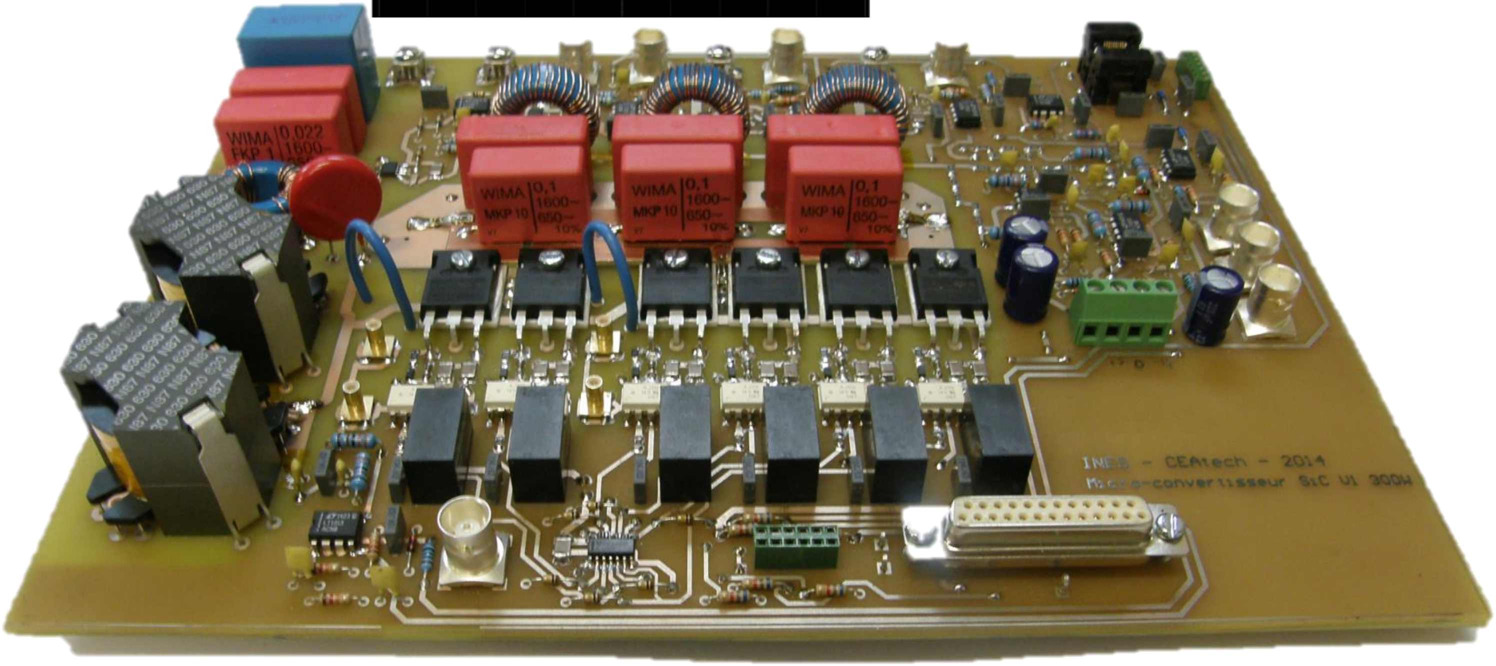
To prevent fire hazards, arc detection for BIPV systems, transferred to industrial partner SOCOMEC

Inverters

Ongoing developments:

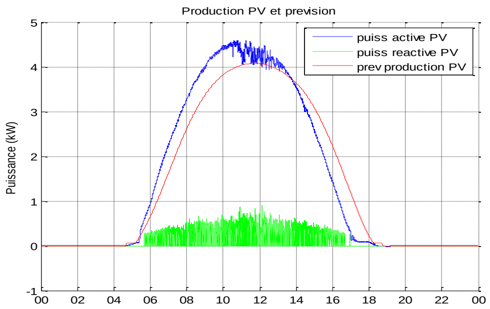
- **Microinverters with SiC switches**
- **Triphase Current source inverter for 300 W PV module**

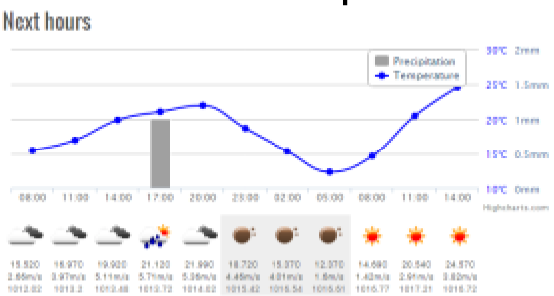




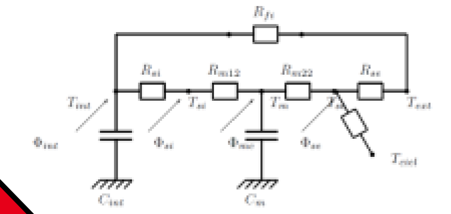
Energy Management Optimisation

Forecasting production / consumption

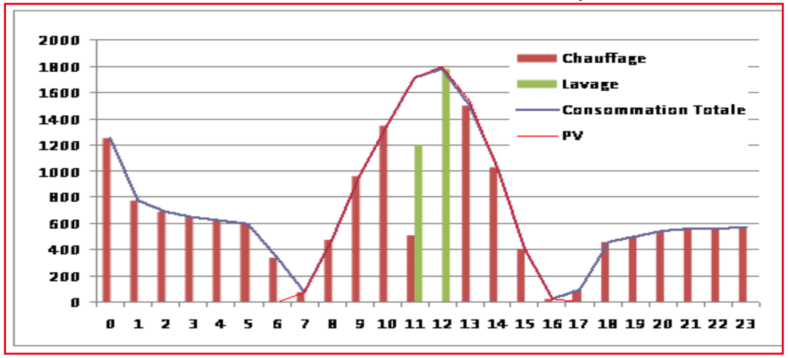


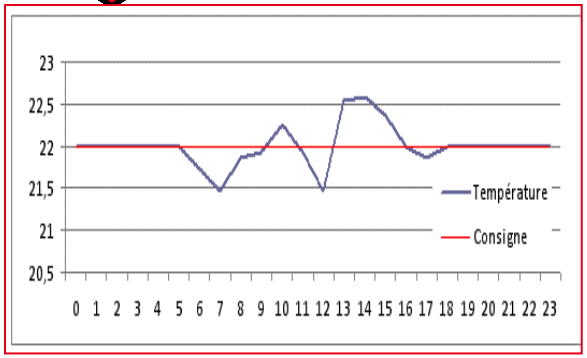


Thermal model and consumption model



Energy management strategy to increase self consumption





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Modelling and simulation challenges, at several scales:

- **At the module level :**
  - Conventional PV module, according to the way it is installed,
  - PVT. See next Thursday at 5pm. 6DO.8.4 “Thermal and electrical performance of solar PVT hybrid air collectors integrated into building”, by YB Assoa.


www.systovi.com

- **At the system level :**
  - PV system
  - PV system coupled to the HVAC system

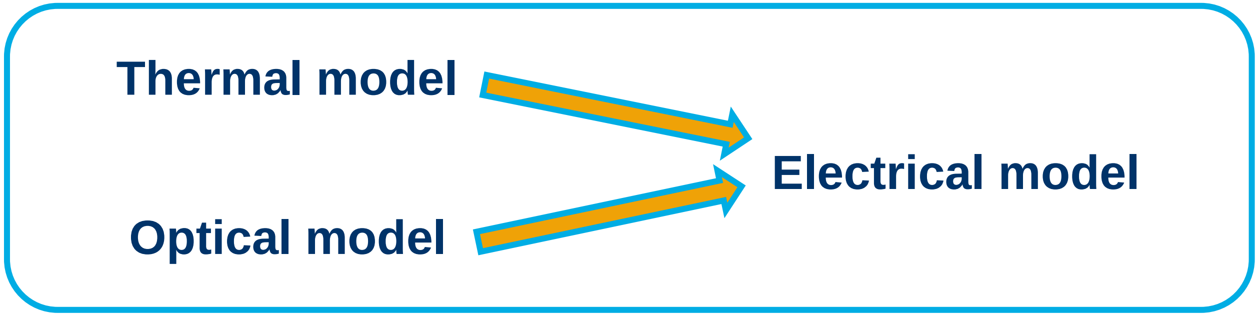
- **At the building level : contribution to the overall energy performance: impact on the R value of the envelope, awnings, sunshading elements**

- **At the district level (heat island effect)**

BIPV MODELLING: MODULE LEVEL

Modelling guidelines

- BIPV systems modelling methods.



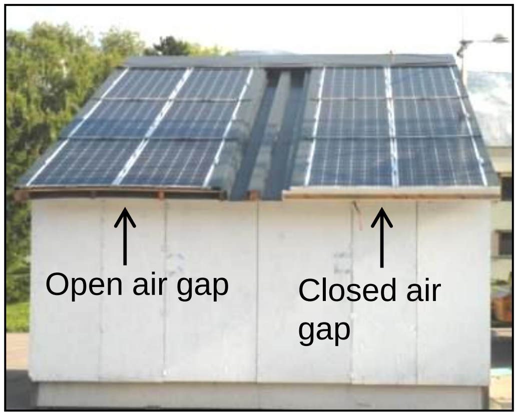
Benchmark of modelling methods

- Results presented at 29th EUPVSEC (Plenary session, 6DP2.3).

- All models examined results in satisfying prediction of module temperatures.
- For practical purposes, the standard linear model is fully satisfactory,

THERMAL MODELLING (1/2)

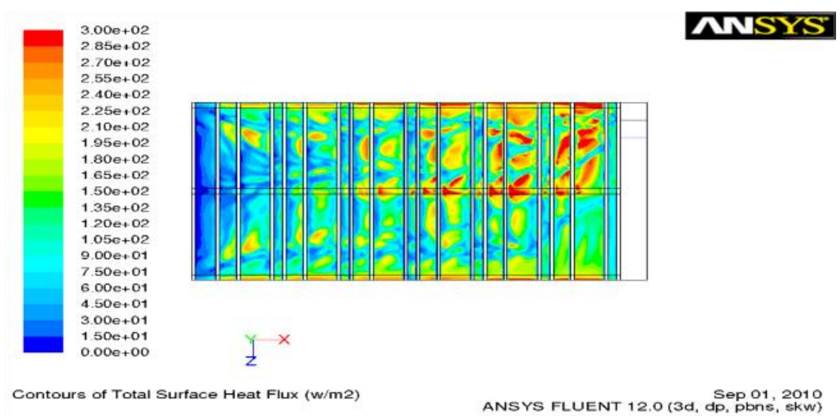
Temperature profiles depending on the types of installation / ventilation :



Test bench

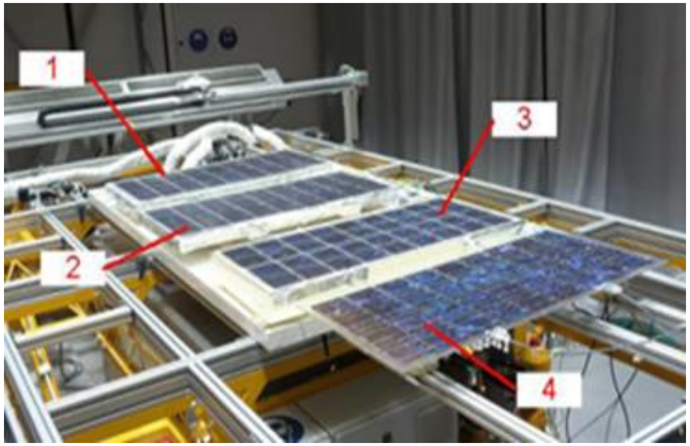
- **No ventilation**
- **Natural ventilation : + 2,5% on the energy output.**
- **Mechanical ventilation : optimization to be made according to the needs**

Modelling of the system behaviour (temperature, heat flux, elecrical production.



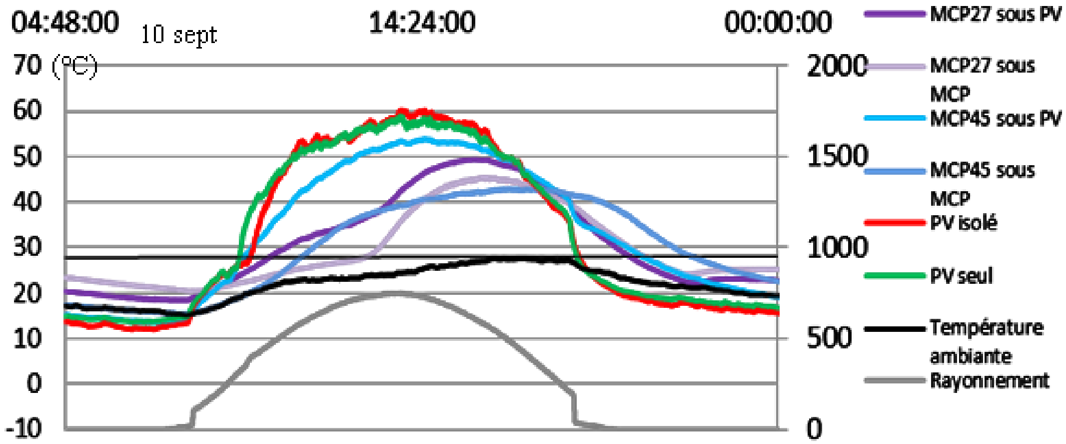
THERMAL MODELLING (2/2)

Temperature profiles depending on the use of Phase Change Material (PCM):



Test bench

Design 1: PCM 27;
Design 2: PCM 45;
Design 3: insulated PV;
Reference case 4: PV only



Energy output increase of **3% to 6% depending on the PCM**.

OPTICAL MODELLING

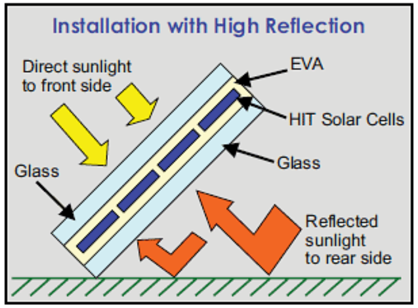
Conventional calculation of irradiation in the plan of array is no longer accurate enough, especially in an urban environment

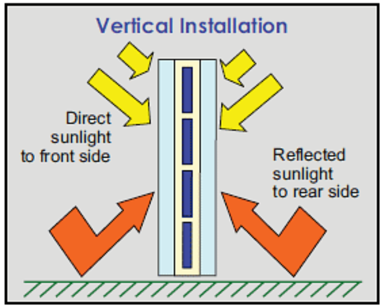
Objectives: To address many shapes, complex geometry, bifacial products and partial shading

To assess concomitance between production and needs

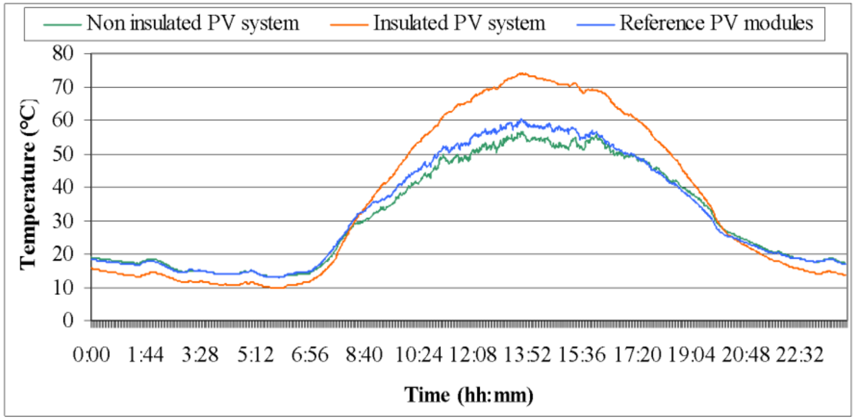
Prerequisite: Ray tracing is required:

- To calculate incident solar radiation all day / all year long
- To assess energy and daylighting performances: daily and seasonal profiles,
- To help in defining a wiring strategy





ELECTRICAL MODELLING



Measured PV modules temperatures in various configurations

Modelling of the system behaviour (temperature, heat flux, electrical production.

- 228 PV tiles connected over 4 strings,
- Energy output optimization requires to insert different numbers of PV tiles per string.

Modelling and simulation issues:

1. Irradiation calculation in a context of multiple orientations, and shading from neighbouring buildings

2. Operative temperature, depending on the design :

- **PV only**

- **PVT, which means heat recovery via air or water, for:**
  - Space heating : GSE, Systovi, IRFTS
  - Cooling (night ventilation)
  - Domestic hot water

Sometimes coupled to a heat pump

www.gseairsystem.fr

The energy performance of the whole system has to be assessed : power, thermal energy recovered, during summer and winter.

BIPV MODELLING: BUILDING LEVEL

Examples of specifically designed BIPV products:

See-Through PV modules

- With cSi cells

Tsukuba building, view from inside

From outside

Examples of specifically designed BIPV products:

See-through PV modules

- **With cSi cells**

- **With thin film technologies**

Cell spacing adapted to lighting, heating and cooling requirements



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BIPV MODELLING: BUILDING LEVEL

ST PV modules (as façades or roof elements) impact many parameters within the building:

- **visual comfort: access to natural lighting and outside view allowance**
- **thermal comfort:**
  - Insulation
  - Increase or reduction of cooling load in summer
  - Increase or reduction of solar gains in winter
- **local electricity production**

Conclusion:

- **Energy saving potential of semi-transparent PV components has to be assessed (EnergyPlus, PVSyst and Relux)**

- **Global energy demand is reduced in climates and buildings where cooling loads prevail over heating loads : tropical locations, commercial buildings, etc.**

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BIPV MODELLING: BUILDING LEVEL

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The same comprehensive approach has to be used for solar protection applications :

- **In buildings**
- **In greenhouses**

BIPV TEST FACILITIES

- **R&D needs to validate models and to develop test procedures of components, products, systems**
- **Collaboration between test facilities (AIT, CEA-INES, Fraunhofer IWES, SEAC, Tecnalia) is important**

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CONCLUSIONS

- **Many products still to be developed**

- **Many issues still to be addressed:**
  - Modelling issues
  - Characterization procedures
  - Lifetime studies
  - Standardization, certification

- **Collaboration between test facilities has to be continued.**

- **According to a recent ADEME study, the potential of PV in buildings in France is 364 GW… Long life to BIPV !**

THANK YOU FOR YOUR ATTENTION