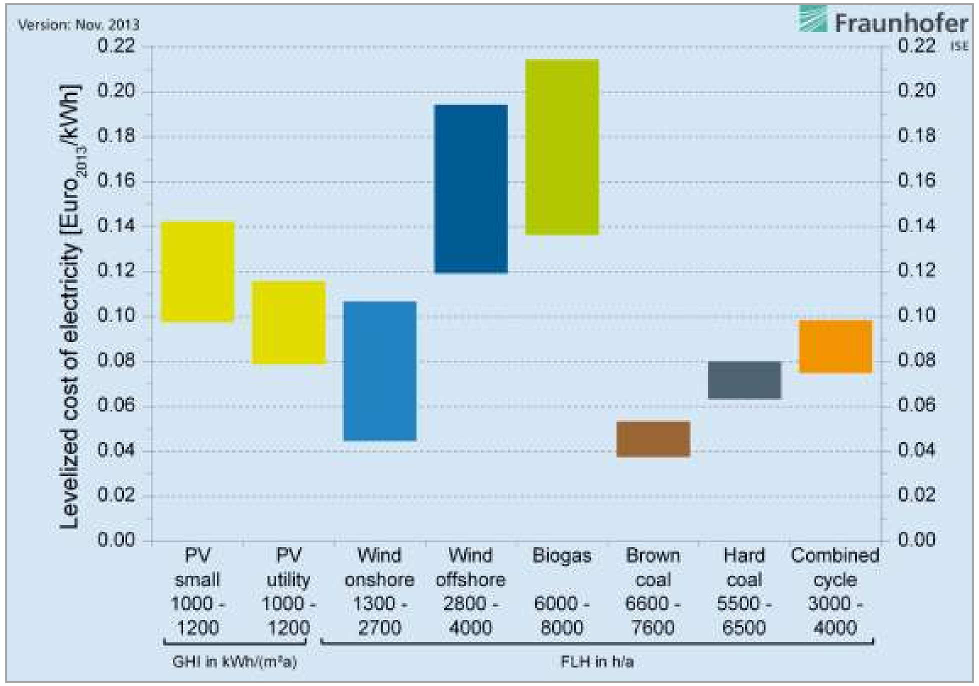
Towards a sustainable energy supply in cities SOLSTHORE

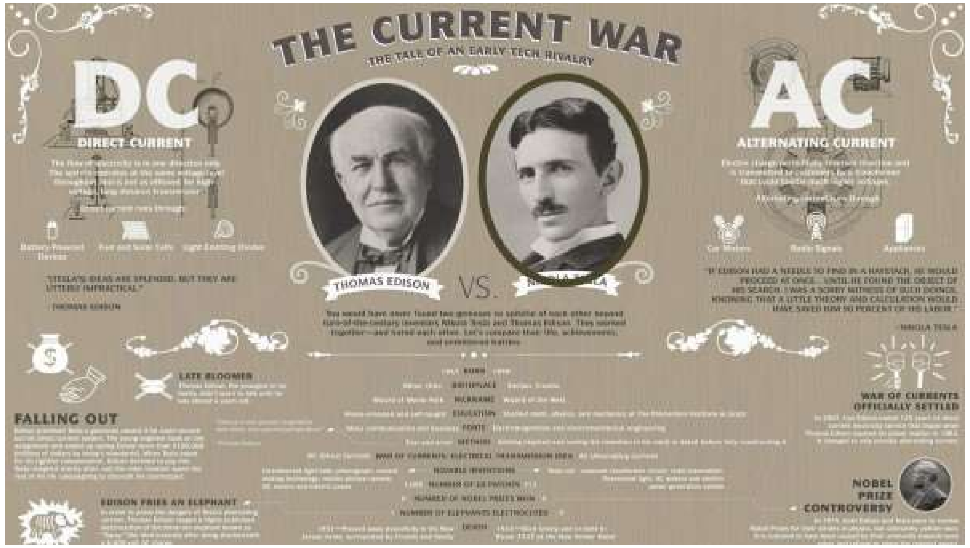
Jef Poortmans, Eszter Voroshazi, An Hardy, Jeroen Büscher, Johan Driesen, Hans Goverde, Kris Baert

SolSThore

What is it about?

- Why this EFRO SALK project:
  - LCOE of PV has reached “grid parity”
  - Further reduction of LCOE requires focus on kWh’s, not only on W_p
  - Requires study/improvement of PV-modules & PV-system integration
  - PV-system + storage system is the name of the game
  - The rebirth of DC





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Bringing the different expertise together ...

- Strong position in PV R&D
  - Global leader in PV-cell technology
  - Presence in other parts of the PV value chain to be reinforced
- .. and is growing in battery research:
  - Material- and cell oriented R&D-activities in imec and UHasselt
  - Battery Management System R&D at VITO
- High potential in linking power device development-expertise to DC-application

Energy Ville

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Project structure

- Activity 1: Innovative cell and module technology
- Activity 2: Towards safe and reliable highly performing local electrochemical storage based on Li-ion system
- Activity 3: Power electronics in a DC-nanogrid context
- Activity 4: Modelling and prediction of energy yield
- Activity 5: Demonstrators in BIPV and commercial roof

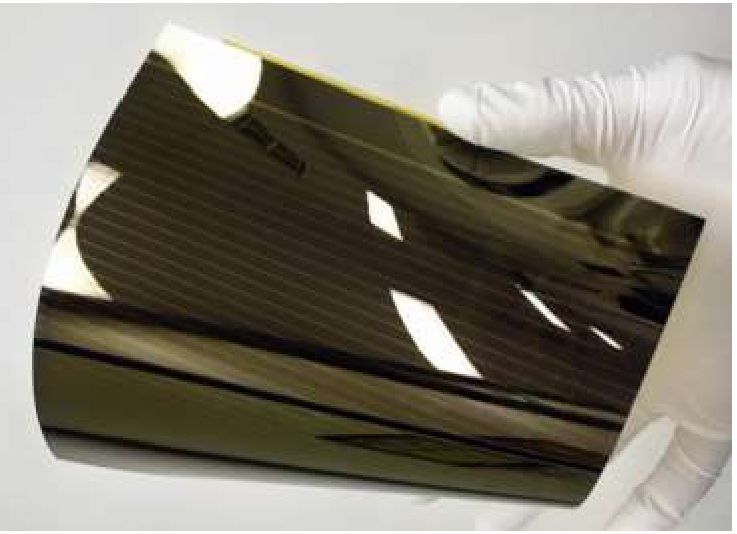
Activity 1
Innovative cell and module technology

Eszter Voroshazi

Technology seeds for world class innovation

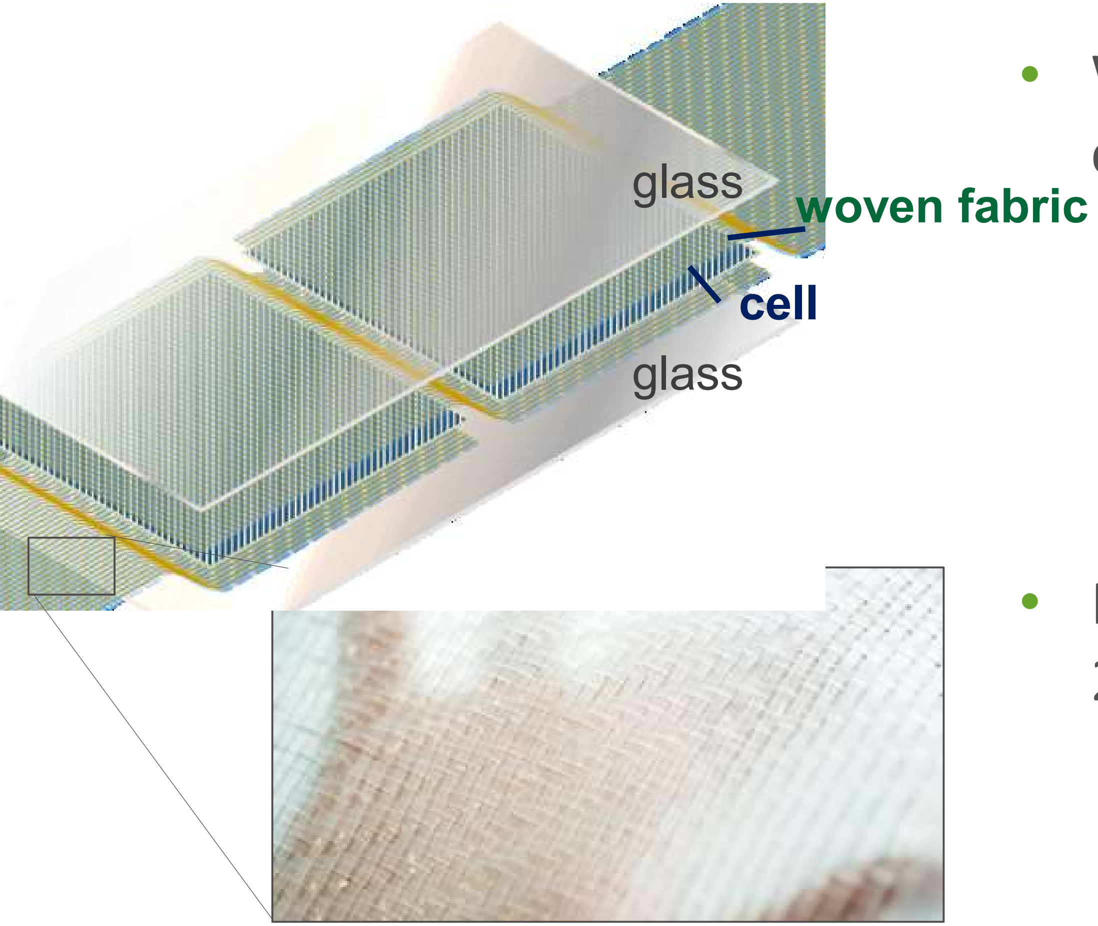
Crystalline silicon PV module technology and characterisation

and their reliability testing &simulations



Thin-film (perovskite) PV module technology

Bifacial cell and module tech' for BIPV

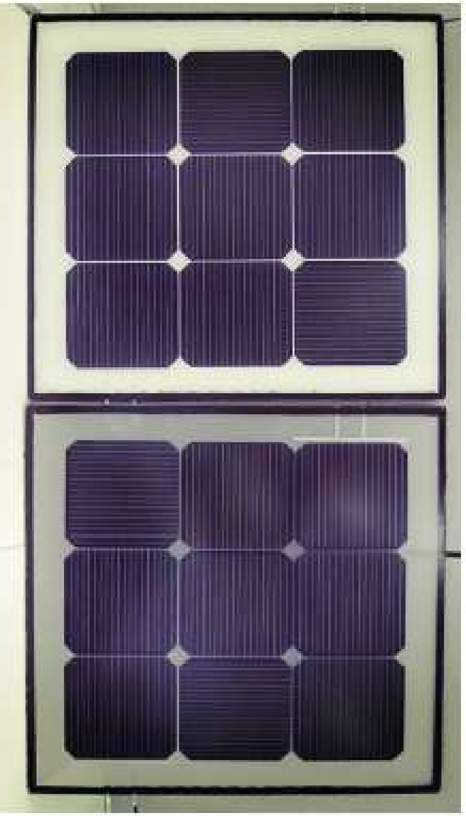


- Woven cell interconnection technology for bifacial cells: from concept to 9-cell demonstration
  - ✓ Optimised woven fabric combines encapsulation and interconnection metallisation in one sheet
  - ✓ Optimised solder and lamination process
  - ✓ Proven <1% CtM current loss (while 1-3% with latest industrial technologies)
- Record performance busbarless and bifacial cells: 22.8% and 98% bifaciality
  - ✓ Integration with SmartWire interconnection proven in 60-cell module
  - ✓ Optimised process to pass 200 thermal cycles < 5% loss
- **Next:** ICON project starting for industrial fabrication of the foils

For more: Poster in EV2 PV lab and live demo in EV2 entrance

3 generations of real-life BIPV demonstrators

2016: 9-cell (10 pcs) modules with industry baseline technology



2017: 9-cell modules (12 pcs) with imec cells and SmartWire interconnection

2018: **60-cell** (5 pcs) and 9-cell (12 pcs) **BIPV modules** benchmarking of latest ribbon and industrial and imec multi-wire interconnection technologies

For more: Activity 5 presentation and demo sites

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(BI)PV module prototyping and characterisation facilities

- cSi BIPV assembly line ($1x1.6m^2$)
  - Automatic module assembly tool
  - Laminator for glass/glass and curved modules
- TFPV assembly ($30x30cm^2$)
  - Laser patterning
  - Slot-die coating
  - Vacuum evaporation/sputtering
- PV module performance and quality testing
  - Bifacial LED based solar simulator
  - Spectral response and reflectivity
  - Material characterisation tools
  - Large area climate chambers

For more: Poster and visit in EV1 and EV2 labs

Activity 3
Development of power electronics

Johan Driesen

LVDC for smart cities

Towards more energy efficiency, distributed generation and internet-of-things

LVDC for smart cities

Towards more energy efficiency, distributed generation and internet-of-things

LVDC for smart cities

Towards more energy efficiency, distributed generation and internet-of-things

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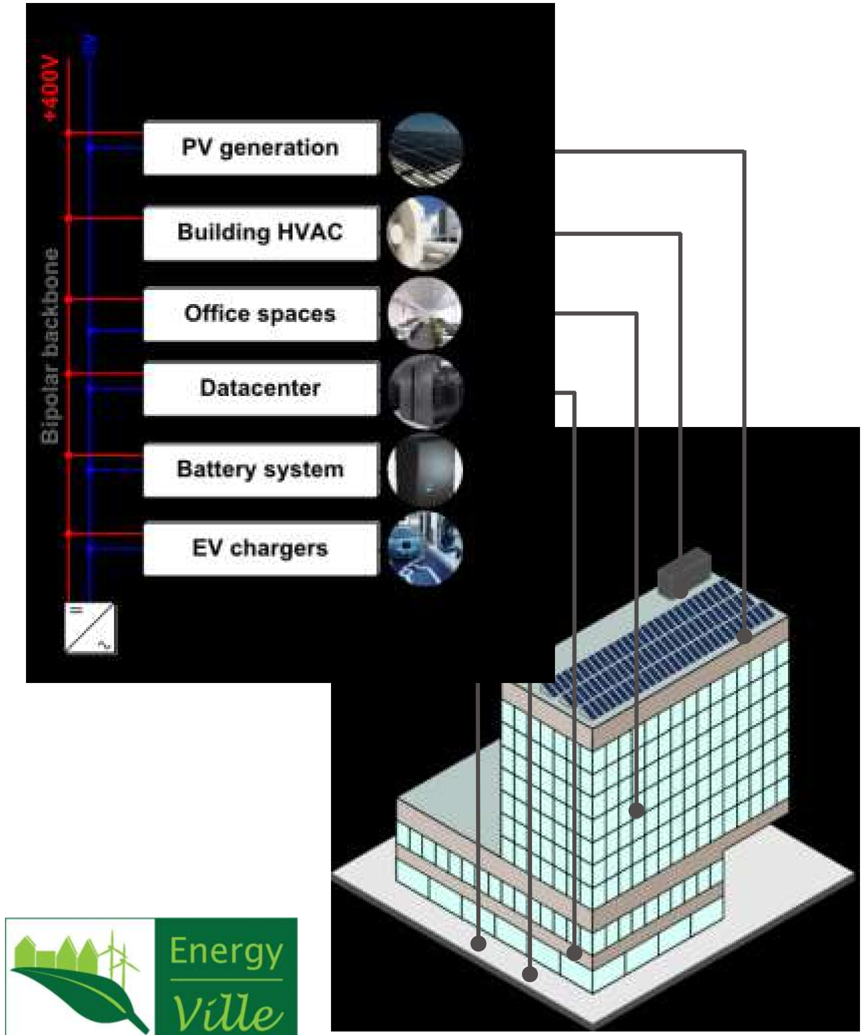
Towards more energy efficiency, distributed generation and internet-of-things

LVDC for smart cities

Three arguments: compatibility, power transfer capability and controllability



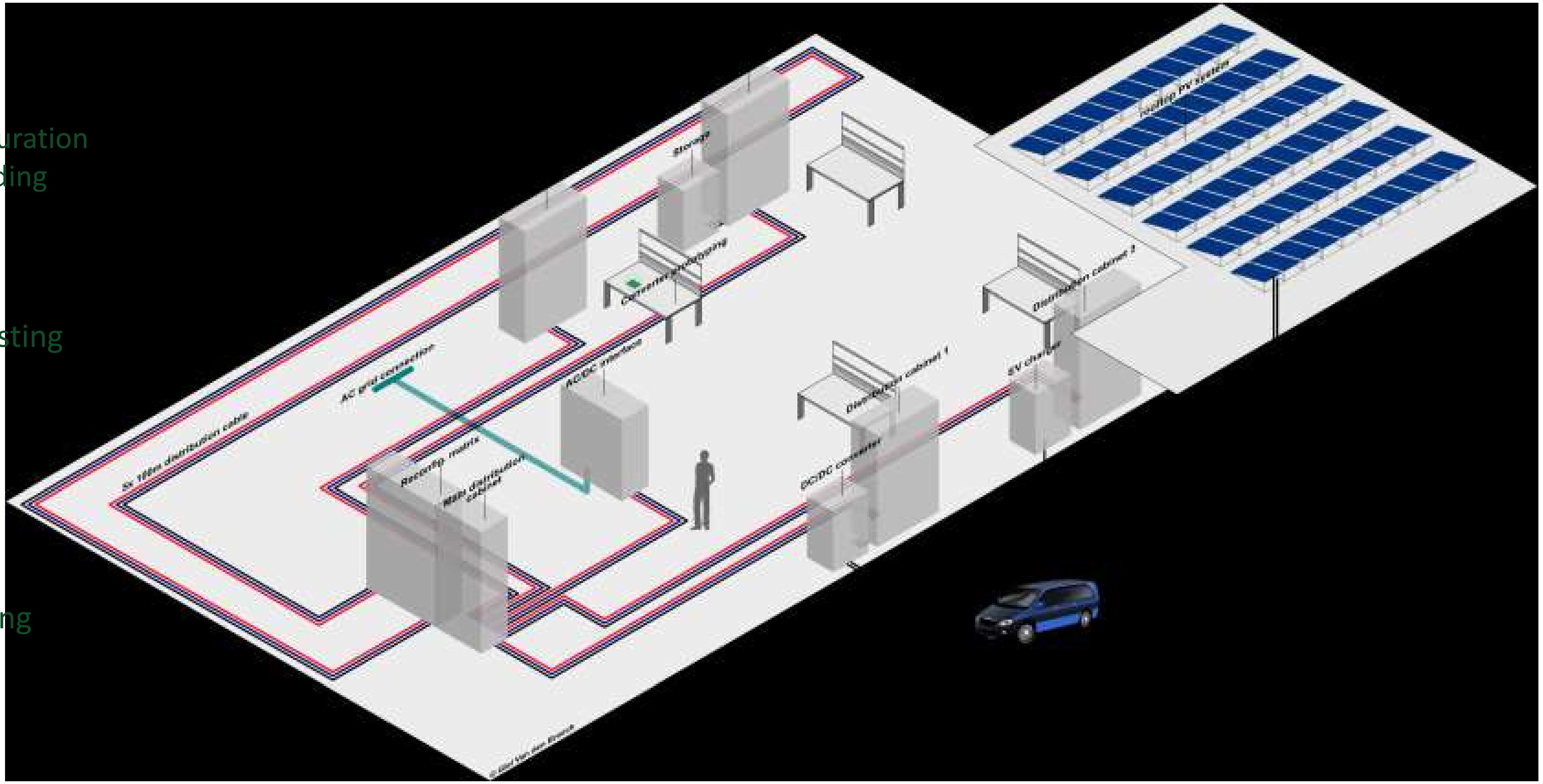
- Motivation for LVDC distribution systems
  - Compatibility with DC devices
  - Increased power transfer capability
  - Increased controllability
- Motivation for **bipolar** LVDC [1-4]
  - Increased power transfer capability
  - Two voltage levels available
  - Conduction losses are reduced
  - Potentially more reliable
  - But: voltage balancing converters required

[1] G. Van den Broeck, S. De Breucker, J. Beerten, M. Dalla Vecchia, and J. Driesen, "Analysis of Three-Level Converters with Voltage Balancing Capability in Bipolar DC Distribution Networks," in International Conference on DC Microgrids, 2017, 8 pages.
[2] H. Kakigano, Y. Miura, and T. Ise, "Low-voltage bipolar-type DC microgrid for super high quality distribution," *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3066–3075, Dec. 2010.
[3] J. Lago, J. Moia, and M. Heldwein, "Evaluation of power converters to implement bipolar DC active distribution networks—DC-DC converters," in *Energy Conversion Congress and Exposition (ECCE)*, 2011, pp. 985–990.
[4] T. Dragicevic, X. Lu, J. Vasquez, and J. Guerrero, "DC Microgrids–Part II: A Review of Power Architectures, Applications and Standardization Issues," *IEEE Trans. Power Electron.*, vol. 8993, no. 99, pp. 1–1, 2015.

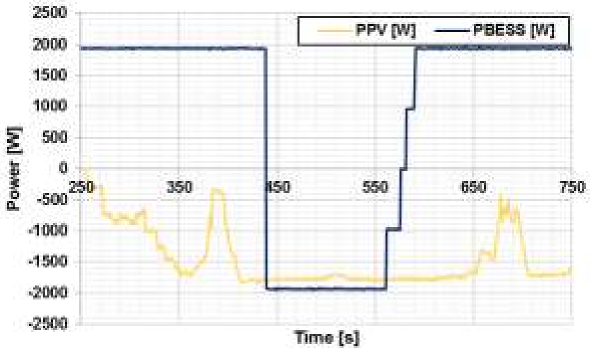
LVDC test facility

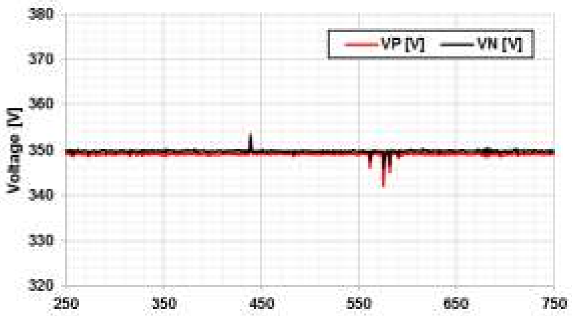
A ±500V bipolar DC test grid developed in the SolSThore project

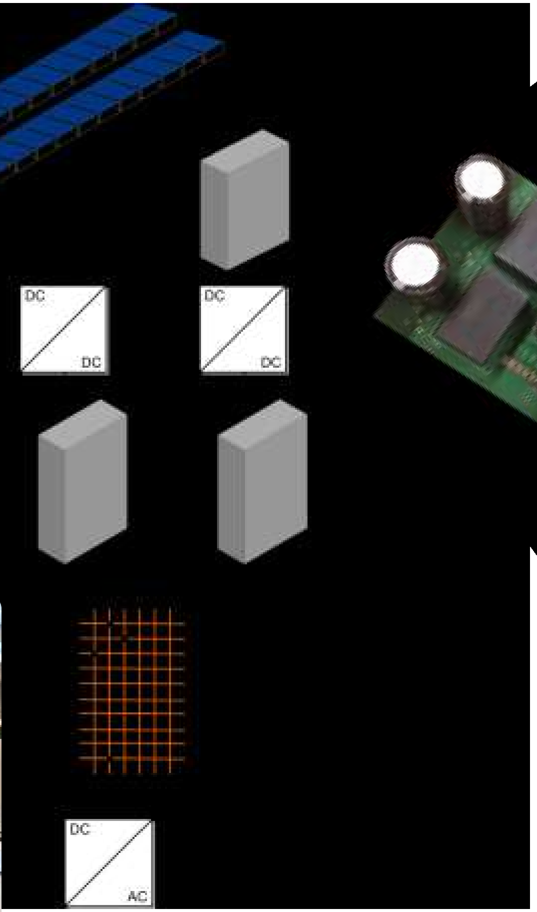
- Lab infrastructure
  - 100 kW ±500V DC test grid
    - Unipolar and bipolar configuration
    - TN-S grounding or IT grounding
    - **Reconfigurable**
  - Power flow monitoring
  - Voltage measurements
  - Power electronic converter testing
  - Communication interfaces
  - Connected to other labs
    - Rooftop PV test site
    - Battery laboratory
    - EV Parking
- Tests
  - Voltage stability - power sharing
  - Protection systems
  - Equipment interoperability
  - Efficiency assessment



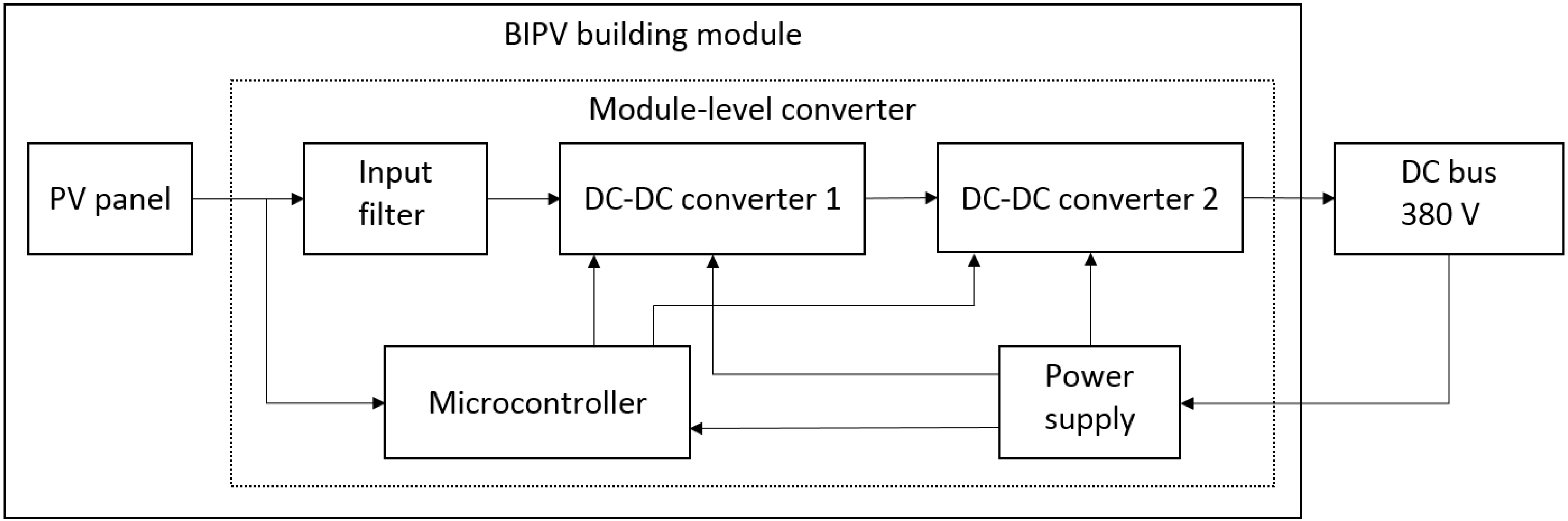
LVDC test facility: example set-up







Place of the DC-DC converter in the BIPV concept



Design specifications - Electrical

- Input voltage: 10 – 50 V
- Input current: max 10 A
- Output power: max 300 W
- Output voltage: 380 V (DC)
  - DC bus gets stabilised by central inverter
  - Unipolar
- MPPT
- Modularity
- Communication with central inverter

Consequences of the required **lifetime**

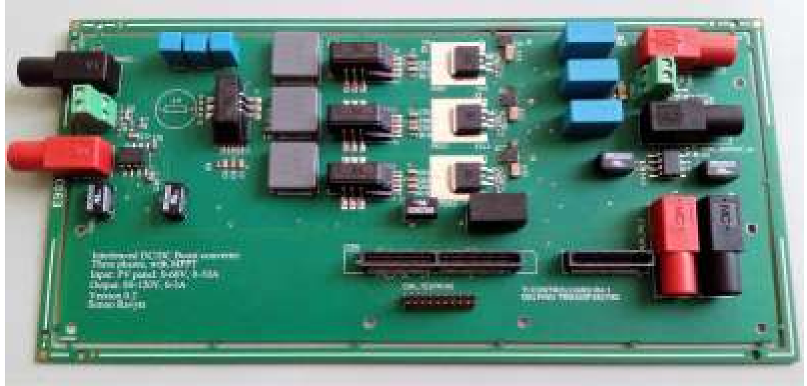
- General design
  - Low component count
  - Simple and robust
  - Limit temperature rise
  - **Redundancy**
  - Use components that are rated up to 125° C
- For cooling
  - Only passive is a viable option
  - Temperature sensors?
- For switches
  - Limit internal temperature (die)
  - Soft switching?
  - Use GaN
- For capacitors
  - No electrolytic capacitors
  - Limit current ripple
  - Limit max voltage

Comparison of Si vs. GaN in circuits: boost converter

- Two PCB prototypes have been developed
  - (a) employs Si MOSFETs
  - (b) employs GaN HEMTs and is three times more compact

(a)

115x250x30 mm³



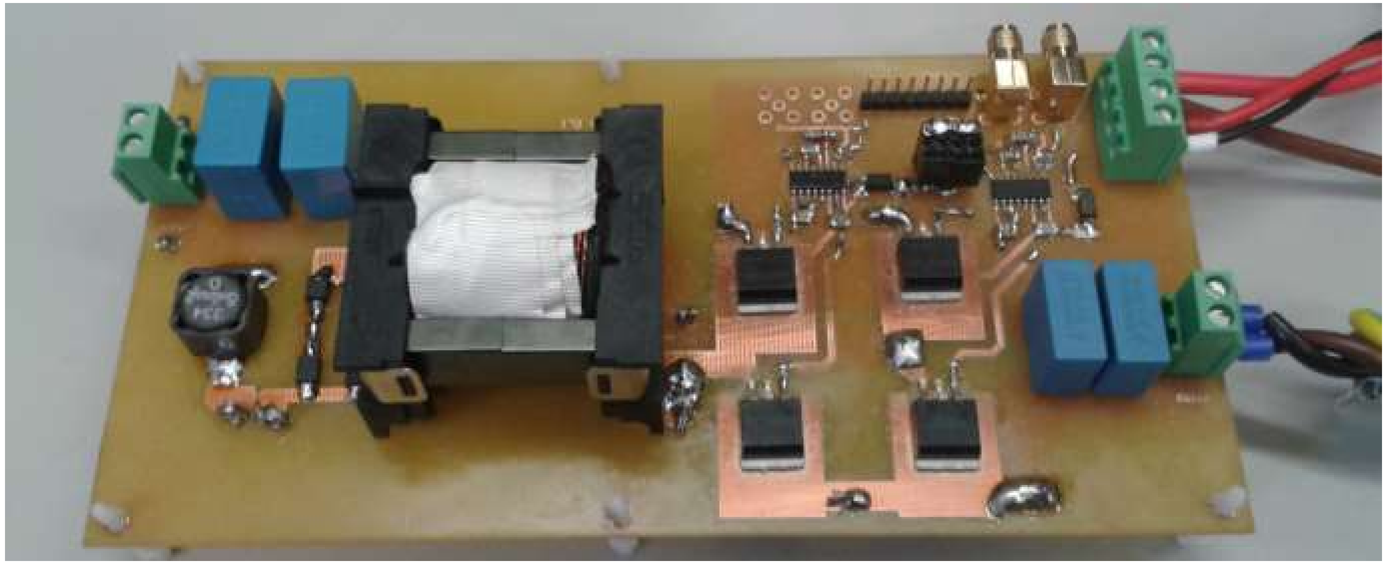
(b)

55x175x30 mm³

Board	Si MOSFET	GaN HEMT
Switching frequency	100 kHz	200 kHz
Switch	Infineon IPB320N20N3	EPC 2047
$V_{ds,max}$	200 V	200 V
$I_{d,max}$	34 A	32 A
$R_{ds,on,max}$	32 mΩ	10 mΩ
$Q_{g,tot,max}$	29 nC	10,2 nC
C_{oss}	180 pF	585 pF
Footprint	10,7x16,05 mm^2	4,6x1,6 mm^2
Diode	VS-10CSH02HM3	VS-10CSH02HM3
$V_{R,max}$	200 V	200 V
V_F	0,75 V	0,75 V
Q_{rr}	53 nC	53 nC
Footprint	6,8x4,8 mm^2	6,8x4,8 mm^2
Inductor	BOURNS SRP1770TA	BOURNS SRP1770TA
Inductance	100 μH	68 μH
$R_{L,DC,max}$	118 mΩ	80 mΩ
Footprint	18,5x12,5 mm^2	18,5x12,5 mm^2
Driver	Silicon Labs Si8272	Texas Instruments UCC27611

Energy Ville

Comparison of Si vs. GaN in circuits: isolated flyback converter



Si Mosfets, bulky transformer with undesired resonances

GaN HEMTs: improved density

Conclusions

- Energy transition at building level: need to rethink the whole internal electricity system
- DC nanogrids allow efficient, affordable, safe integration of BIPV, storage, smart loads
- Living lab meeting safety standards constructed at EnergyVille
- Power converter development using GaN technology

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Activity 4
Modelling and Forecasting PV Energy Yield

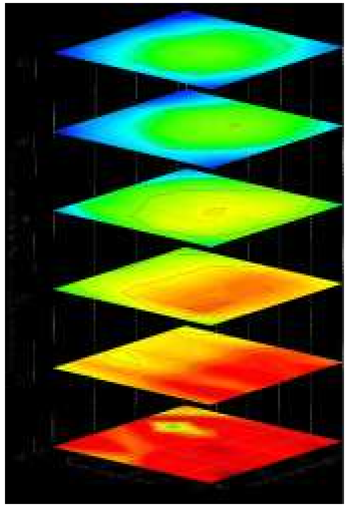
Hans Goverde
(Georgi Yordanov)

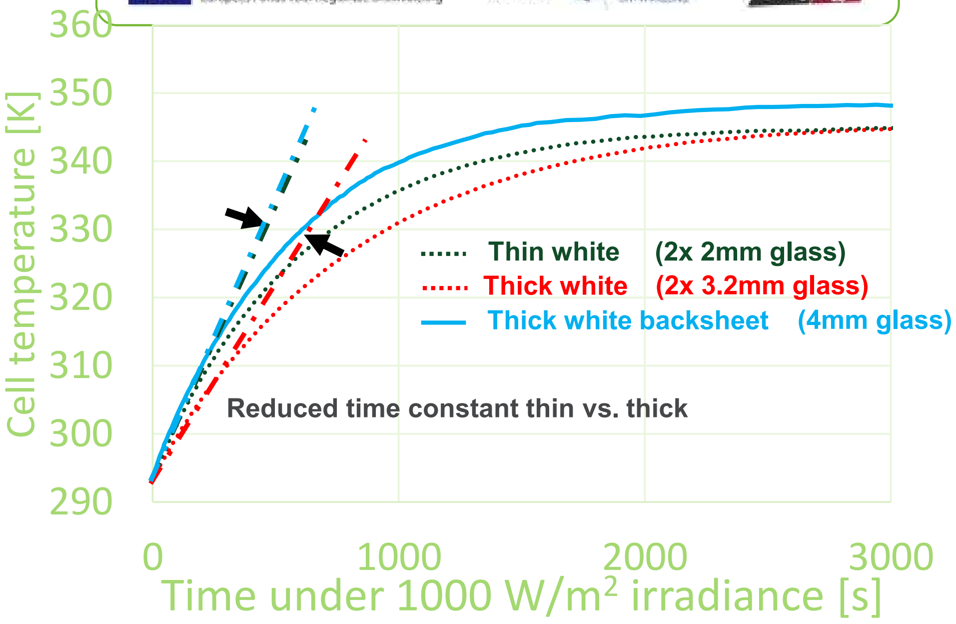
KU LEUVEN

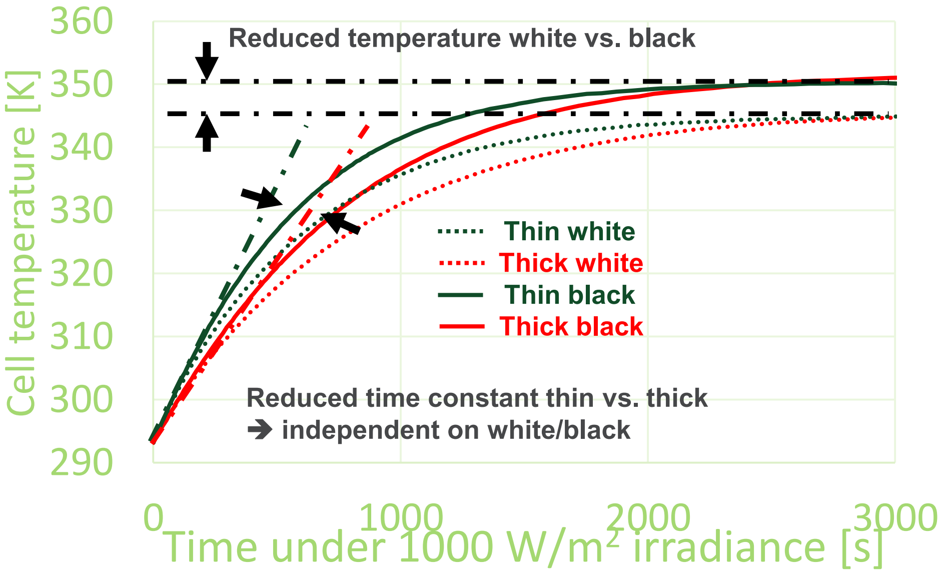
SolSThore – Activity 4

Indoor characterisation

- Development of dedicated characterisation tools and measurements







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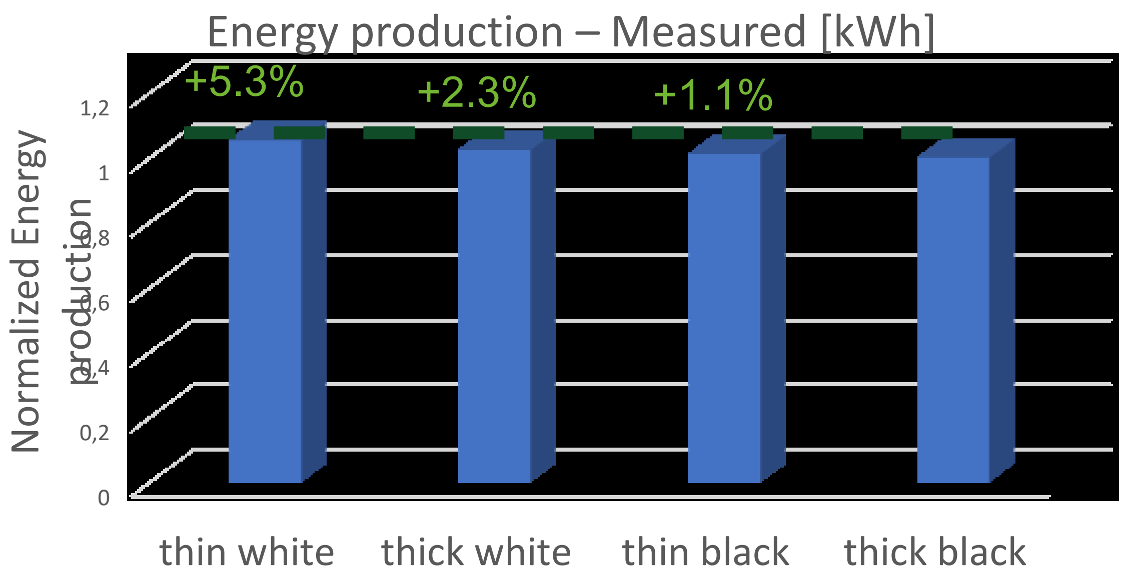
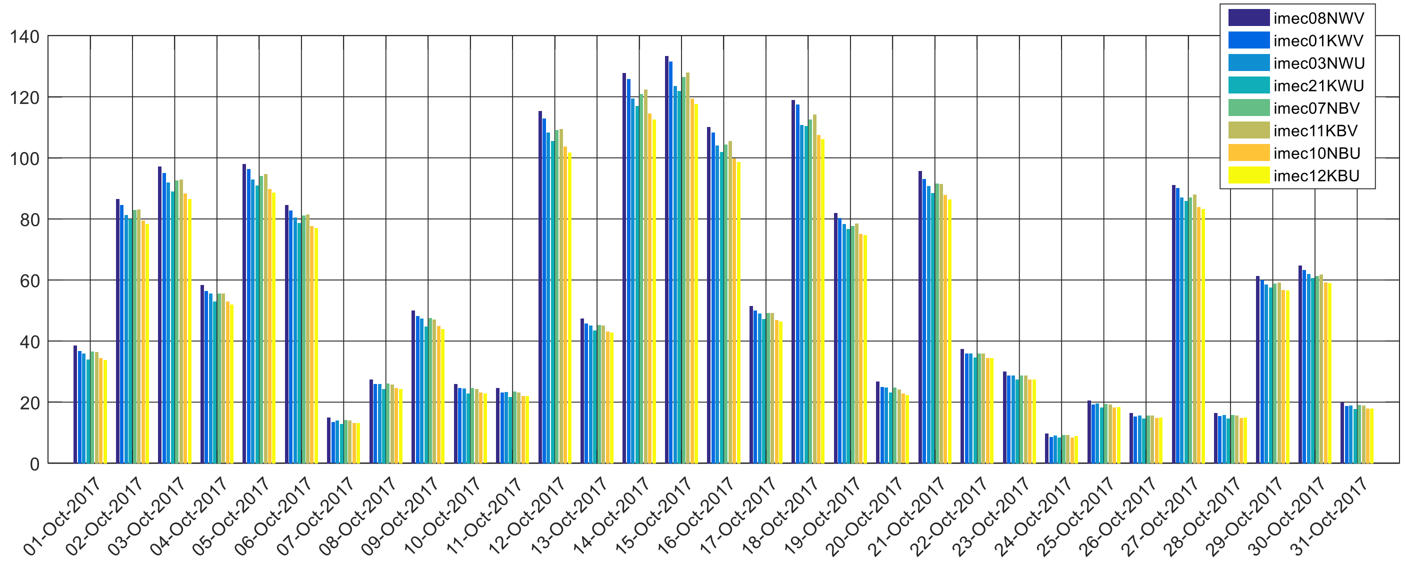
Outdoor measurement





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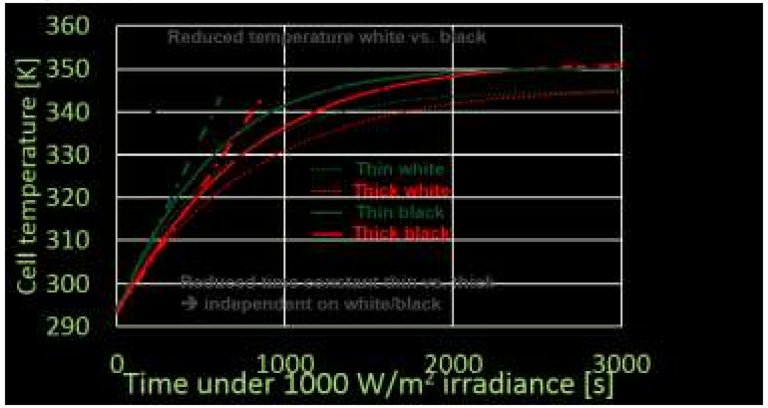
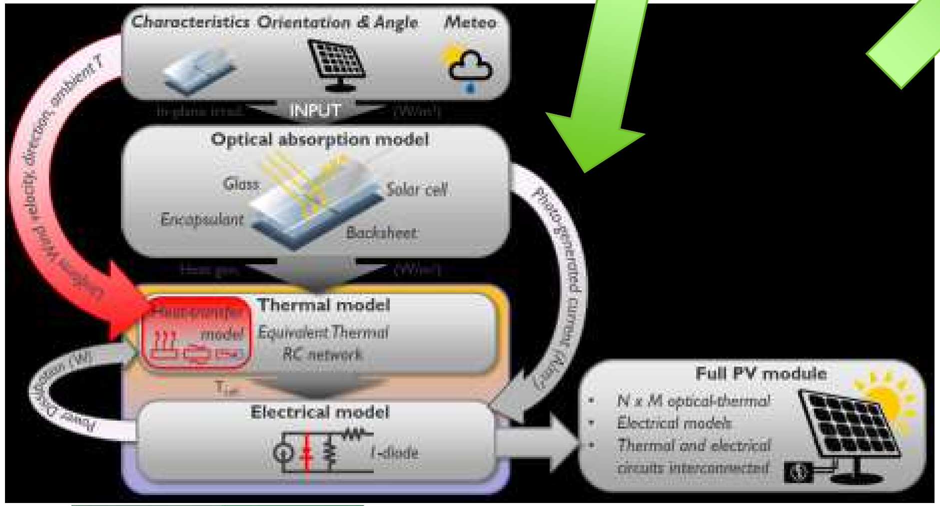
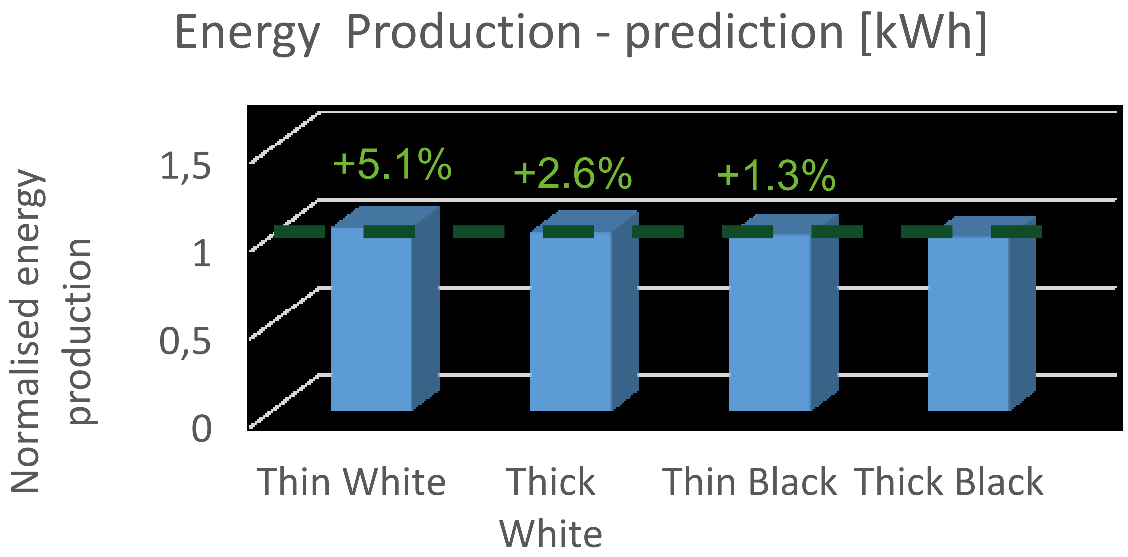
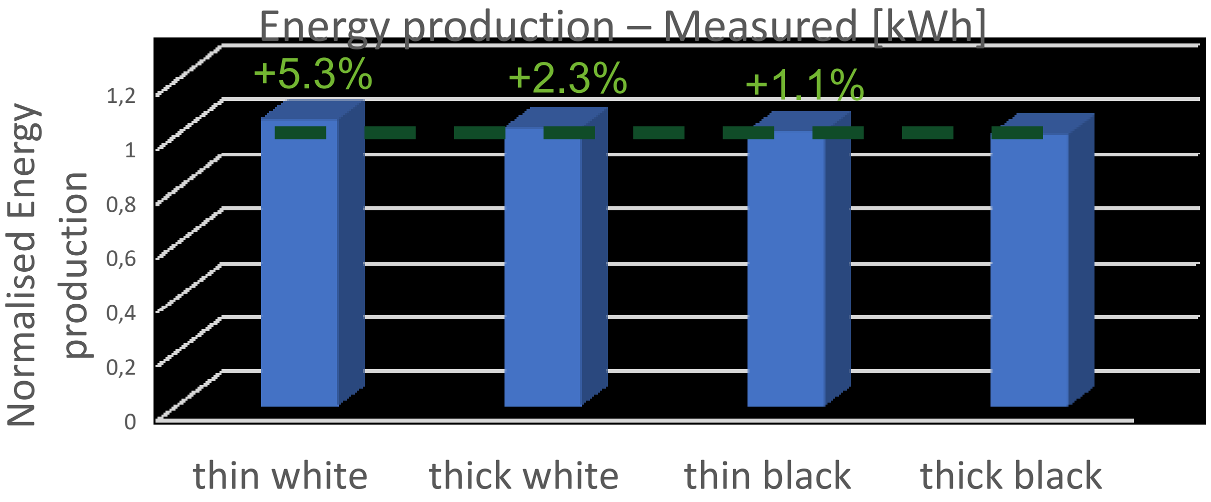
Energy yield Simulations









Activity 5
PV system demonstrators

Kris Baert

SolSthore Activity 5 : PV system integration

- PV integration in facades

- Commercial roof PV connected to a bipolar DC grid -> see
  - poster : Low Voltage DC grid (EV-1, 2F, Home Lab)
  - demo : rooftop PV installation (EV-1)

- Grid compliance testing by Real-Time Grid Emulator-> see
  - Poster : Grid Compliance Testing of DC/AC PV Inverter (EV-1, Matrix Lab, 0F)

The case for integration of PV in facades of high-rise buildings

2020 NZEB directives => enhanced use of PV on buildings

- rooftop area for PV often scarce
- aesthetics suited for office-buildings
- high facade engineering capacity
- benign to the local grid (congestion !)
    - generation close to consumption
    - in sync with airco load
    - East – South – West facades => flatter day profile
    - seasonal profile
- façade cost Euro/m^2 marginally increased and compensated by enhanced “greening”

Heron Tower London

The case for PV in "curtain walls"

- Industrially pre-fabricated
- Semi-standardized dimensions
- Millions of m^2 / year of facades installed

- **multi-GW /yr. production opportunities for PV for facade-integration**

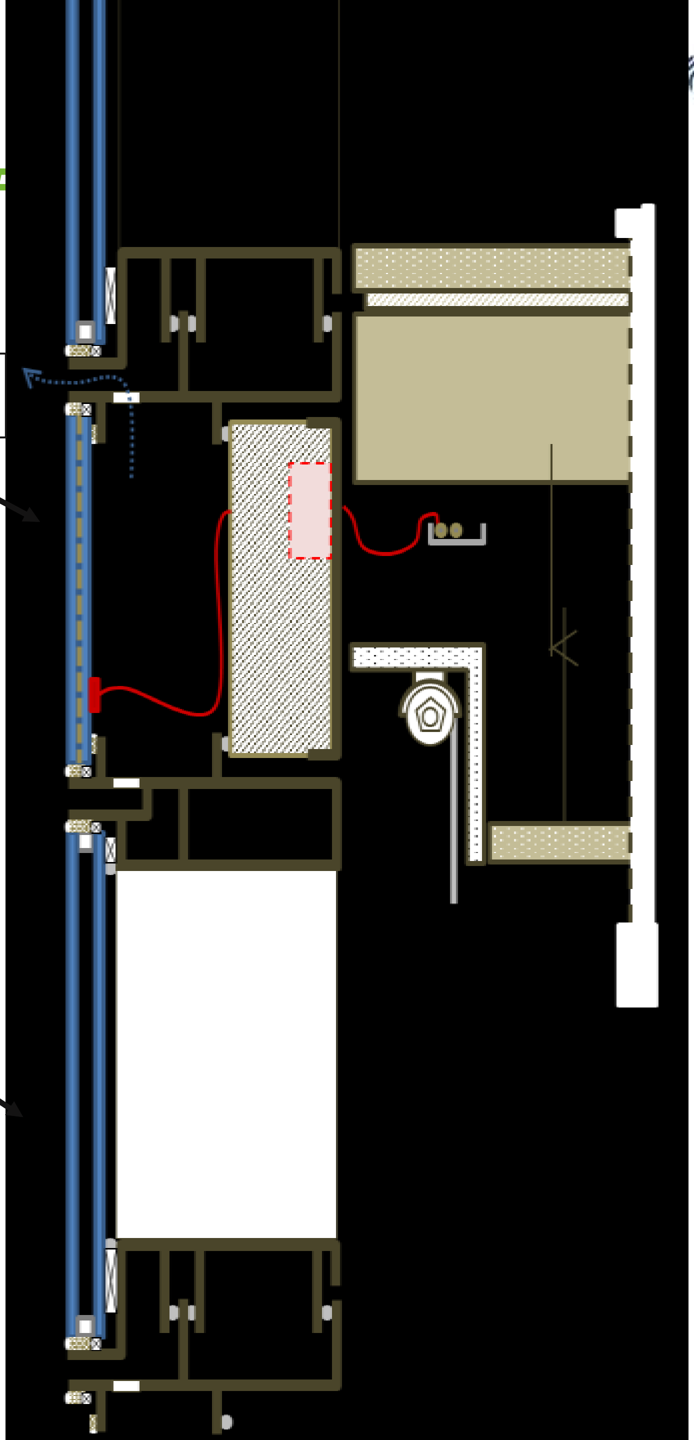
Prototype: PV in curtain wall

=> See Demo “Curtain wall BIPV” in Matrix Lab (0F

Ventilation holes

PV module

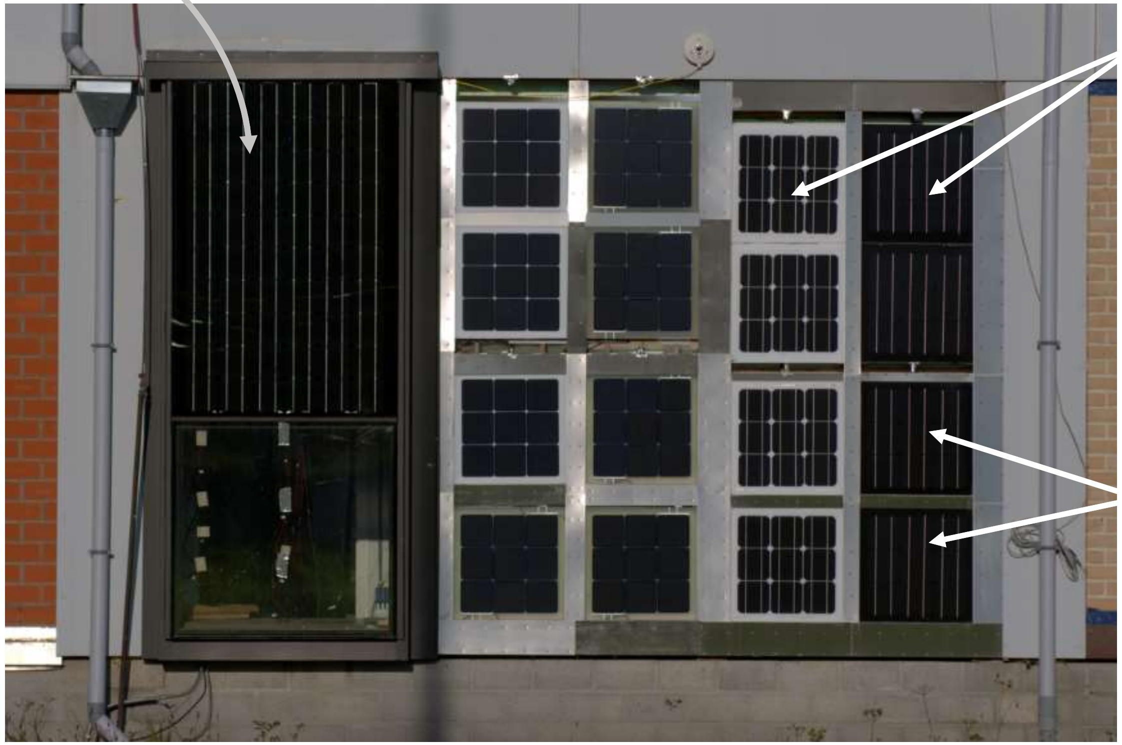
Glass



Thermal and electrical performance

Curtain wall BIPV element feeding into DC Nanogrid

- Temperature distibution
- Energy yield
- DC/DC converter effic



Impact of black vs. white backsheet in PV module:

- on operating temperature
- on energy yield

Impact of ventilation :

- on operating temperature
- on energy yield

=> See Poster "BIPV set-ups" in Matrix Lab (EV-1, 0F)

What’s next ?

- Frame integration of EnergyVille’s DC/DC converter
- Develop, test and model other facade-BIPV building solutions
    - for non-office buildings
    - for integration in solar shades
    - …

See demo : Facade-BIPV panels on East – South- West of EnergyVille-2 (2F)

Eager to find out more?

The scientific publications developed during the project can be found using the QR-code