Colouring technologies for BIPV modules
• A Review •

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Speaker: Florian Ollagnon

Integrated Photovoltaic Conference

EPFL PV-lab IEM NEUCHATEL :: csem

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Building-Integrated PV

Motivations

Buildings In The EU

- 40% EU energy consumption
- 36% GhG emissions

Nearly-Zero Energy Buildings by 2030 (ZEB by 2050)

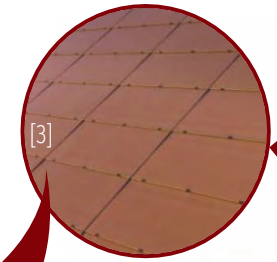
Energy Performance of Buildings Directive – *European Parliament & Council* [1]

Art. 2

Energy perf. of building

- primary energy **consumed**
- share of energy requirements **supplied** from **REn**

BIPV


[3]

BIPV Colouring techniques

- Efficiency *vs* Aesthetic
- Cost
- Reliability

Why color for PV?

- *"Transformative solutions"* for PV modules
- In a slogan: "PV is there, but is not to be seen"
- Adding color is simple way – not the only way – to modify visual impact of modules
- Can increase **social acceptance** in urban contexts and willingness of architects to "play" with BIPV
- Today there's plenty of solutions that were not available only few years ago

PV Magazine, Nov 2024

Custom-colored modules increase social acceptance of building-integrated photovoltaics

A study by the University of Freiburg and the Fraunhofer Institute for Solar Energy Systems finds that deploying color-matching solar modules on a building's roof or facade further increases social acceptance of building-integrated photovoltaics (BIPV).

NOVEMBER 14, 2024 PATRICK JOWETT

COMMERCIAL & INDUSTRIAL PV | INSTALLATIONS | MANUFACTURING | MARKETS | MODULES & UPSTREAM MANUFACTURING | RESIDENTIAL PV | TECHNOLOGY AND R&D | GERMANY

A building in Eppingen, Germany, with a red roof-integrated PV system

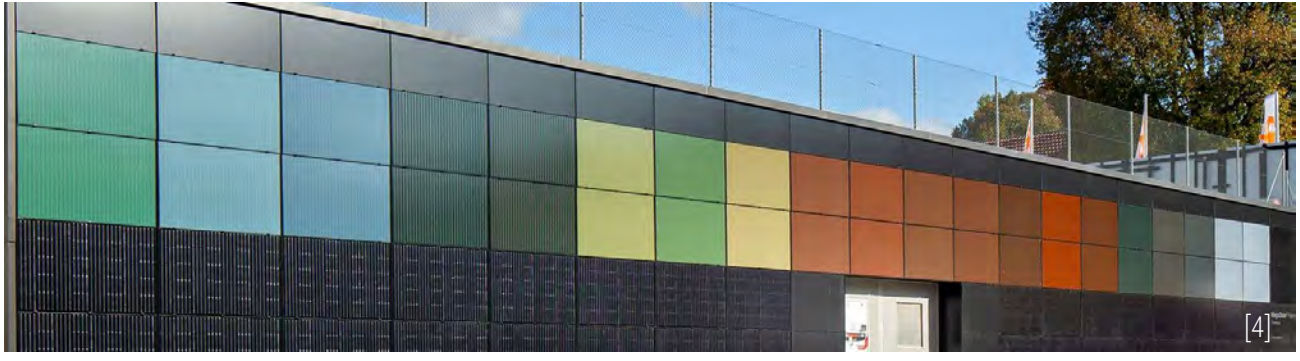
Image: Sarah de Carvalho/Fraunhofer

Colouring techniques for PV

Coloured glass

Digital Ceramic Printing (DCP)

MegaSlate Flair , 3S Swiss Solar Solutions AG
Test installation DCP coloured modules in Bern (CH)

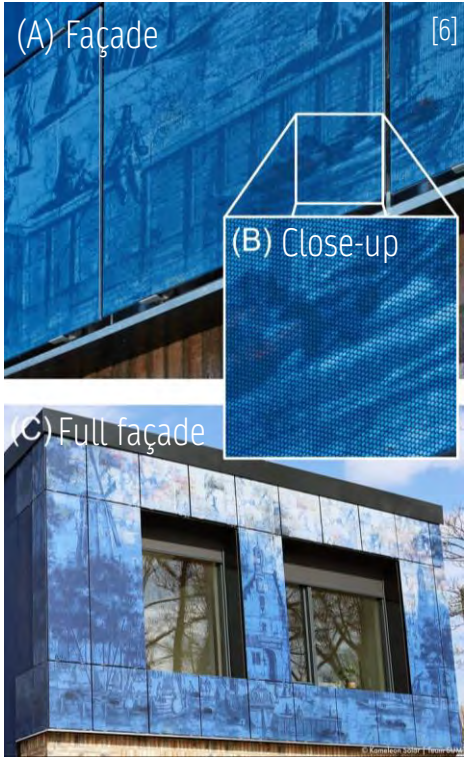


Mass-coloured glass

Ceramic Colors Wolbring,
Colorquant portfolio test samples

Screen printing

Kameleon Solar, SUM prototype



Colouring techniques for PV

Coloured Interlayers

Colour encapsulants

3S Swiss Solar Solutions AG
Terracotta foil BIPV modules, Zurich (CH)

Freesuns
Heritage solar tiles (CH)

Solaxess
White BIPV façade (CH)

Colouring techniques for PV

Coloured Interlayers

Coloured semi-transparent PV active layers

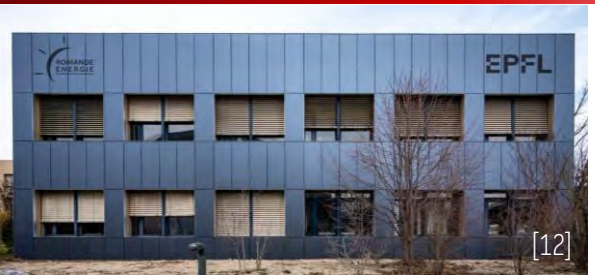
Onyx solar
*Project for DEWA R&D with **see-through coloured a-Si** [11]*

***Vanceva coloured foils** (!! **Not PV by itself**, but good for **association with a-Si** to obtain colorful semi-transparent PV glazings), e.g. for Onyx a-Si modules)*
Computer Science Building, Belfast University [10]

Colouring techniques for PV

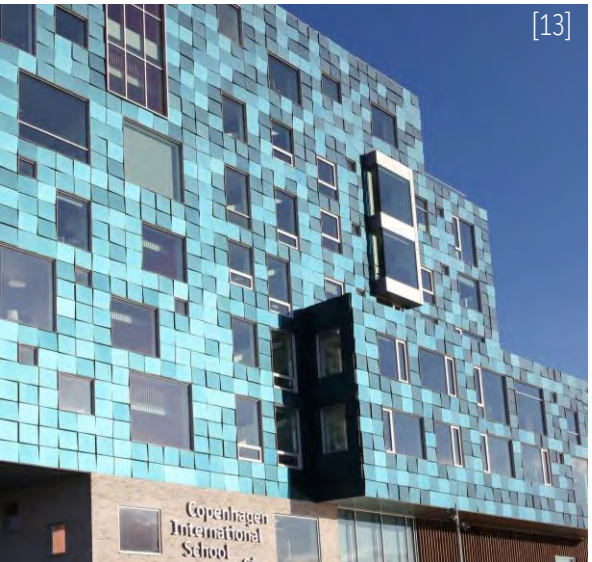
Coating

Interferential coatings



[12]

EPFL Campus (CH)
Kromatix, Swissinso
Blue-green Kromatix glass Copenhagen International School (DK)



[13]


[14]

*Pilot installation of **MorphoColor color layers** on the BIPV demonstration stele in front of the main building of the **Fraunhofer ISE** in Freiburg (DE)*


[15]

Solaxess
1st generation of white foil, BIPV façade (CH)

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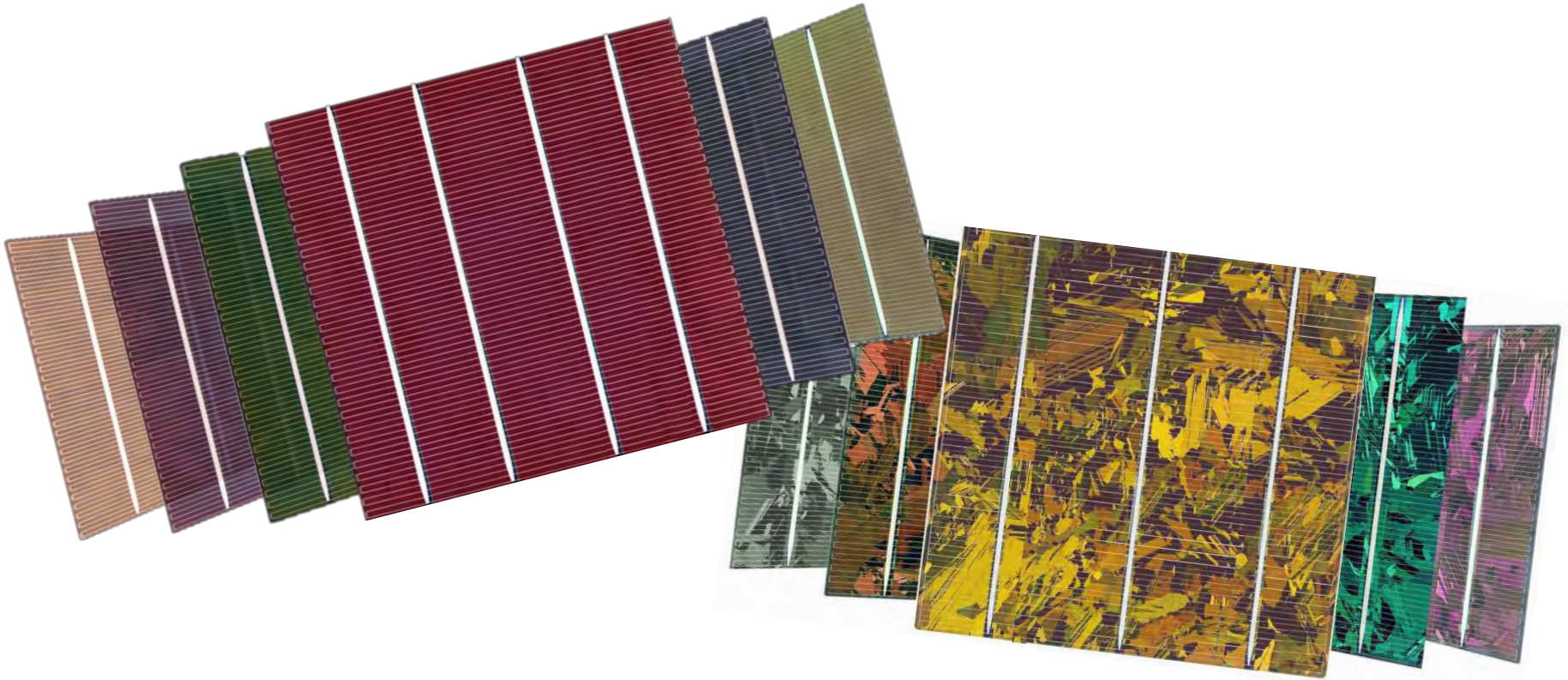
Coloured cells

LOFsolar coloured Si cells [17]

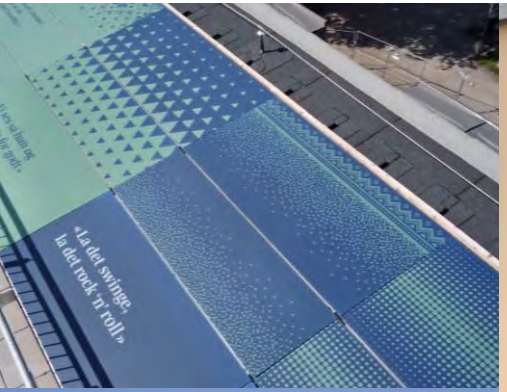


Colouring techniques for PV

Post-manufacturing colouring

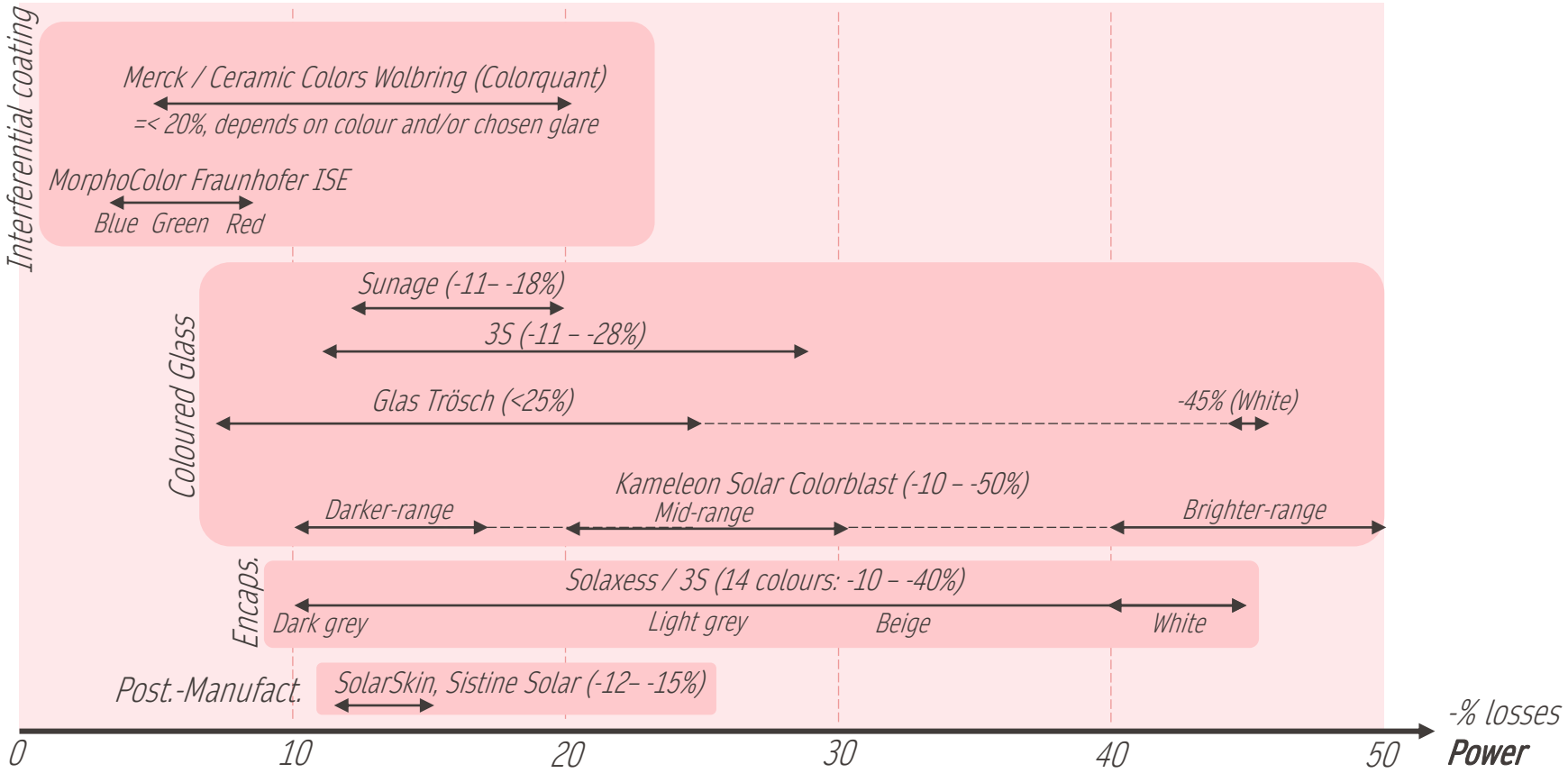
Retrofit / Art & Design projects

Compáz (CH)
Examples of realizations using coloured PV modules [21]



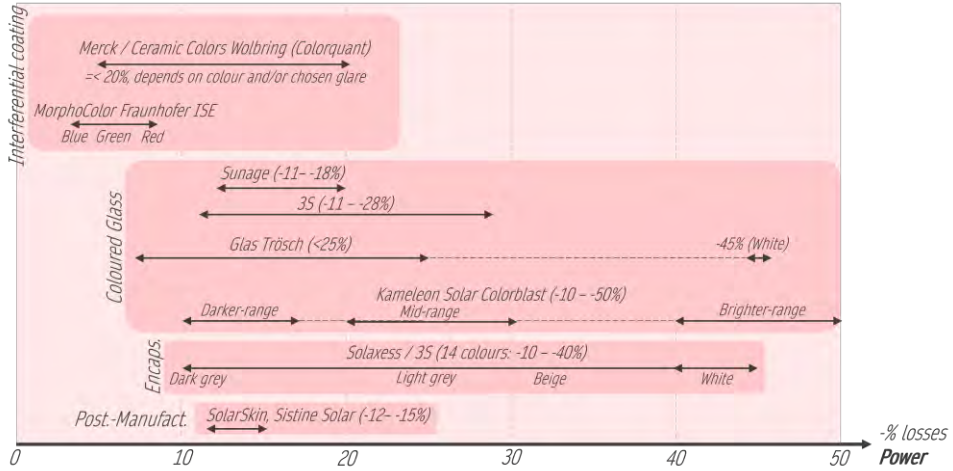
Colouring techniques for PV

Performance [22]



Colouring techniques for PV

Performance [22]



Performance **losses** (*vs* standard module):

➔ Highly **dependant** on **technology** and **colour**

➔ Compromise: **aesthetic** ↔ **performance** ↔ **cost**

Colouring techniques for PV

Cost [22]

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Standard PV modules, conventional architecture, mass-manufactured in China:

30—40 €/m² wholesale market (20% eff. Modules, 0.15 eur/Wp (end 2023 prices)

*➔ 2-3x higher small-scale **residential** systems*

Reason & Prediction:

- *Project-dependant / **customization***
- ***Niche** market ➔ **Small** manufacturing **volume*** (10—100 + MWp/y for BIPV *vs* 10 + GWp/y for mainstream products)

BAPV (Building-Applied PV) rooftop prices in EU, using mainstream Chinese products:

200—600 €/m²

BIPV (Building-Integrated PV):

- *100—400 €/m² (type, size, materials, manufacturing volume)*
- *Up to 800 €/m² for **super-bespoken** products*

Colouring techniques for PV

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BIPV **replace** structural elements of Building ➔ **Deduct** materials **costs**

➔ **Some** techno. = in **price range** of typical **cladding materials**
Bricks (60-100 €/m²) or Wood (50-180 €/m²) [23]

+ additional benefits of **energy generation**

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Colouring techniques for PV

Conclusion

- Multiple solutions, products and companies active
- Performance (i.e. losses) dependent on Technology and Colour
- Aesthetic ↔ performance ↔ cost
- Stability of coloring solutions over time is critical in development
- Cladding materials and BIPV in similar range price

A. Borja Block, et al., **"Colouring solutions for building integrated photovoltaic modules: A review"**, 2024. *doi: 10.1016/j.enbuild.2024.114253.*

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Thank you!

Longer version of the presentation available upon request

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Great teams ;)

EPFL PV-Lab

~40 peoples at EPFL PV-Lab

CSEM Sustainable Energy Center

~100 people in CSEM Sustainable Energy Center

References

[01] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/nearly-zero-energy-buildings_en
[02] Figure from: HZB Home https://www.helmholtz-berlin.de/projects/baip/bipv_en.html
[03] Building in Zürich, Switzerland, with terracotta foil. 3S Swiss Solar Solutions AG
[04] Test installation of MegaSlate Flair DCP coloured modules in Bern with a varied range of colours. Image courtesy of 3S Swiss Solar Solutions AG.
[05] SUM prototype from Kameleon Solar. (A) Façade. (B) Close-up of the small spaced out DCP hexagons. (C) Full façade. Images provided by Kameleon Solar, Team SUM
[06] A portfolio of Colorquant product samples from Ceramic Colors Wolbring. Image provided by Ceramic Colors Wolbring GmbH
[07] Building in Zürich, Switzerland, with terracotta foil. Images provided 3S Swiss Solar Solutions AG
[08] Freesuns project in Ferlens, Switzerland, with different tones of terra cotta solar tiles. (A) Distant perspective. (B) Near perspective. (C) Close-up view. Images courtesy of Freesuns
[09] Solaxess
[10] Computer Science Building of the University of Belfast with Vanceva coloured foils. (A) Main entrance. (B) Façade. Images courtesy of Vanceva
[11] Project for DEWA R &D from Onyx solar employing see-through coloured a-Si. Image provided by Onyx solar
[12] First building equipped with Kromatix technology at EPFL main campus. Images courtesy of Kromatix ™ SA
[13] Iconic BIPV building of the Copenhagen International School with blue green Kromatix glass. Images courtesy of Kromatix ™ SA
[14] Morphocolor Fraunhofer ISE
[15] BIPV building made with a Solaxess nanotechnology white film. Image courtesy of Solaxess
[16] LOFSolar
[17] Examples of realizations using coloured PV modules by Comp´az. Images courtesy of Association Compáz
[18] A. Borja Block et al., “Colouring solutions for building integrated photovoltaic modules: A review,” Energy and Buildings, vol. 314. Elsevier BV, p. 114253, Jul. 2024. doi: 10.1016/j.enbuild.2024.114253.
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