

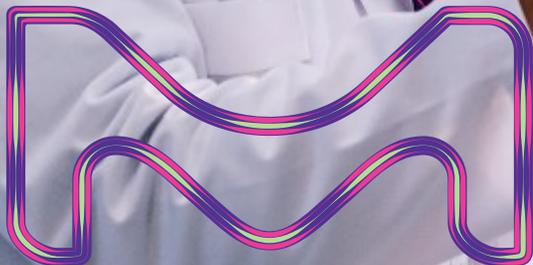


New design options for photovoltaics

ColorQuant™ Technology

Sebastian Barth

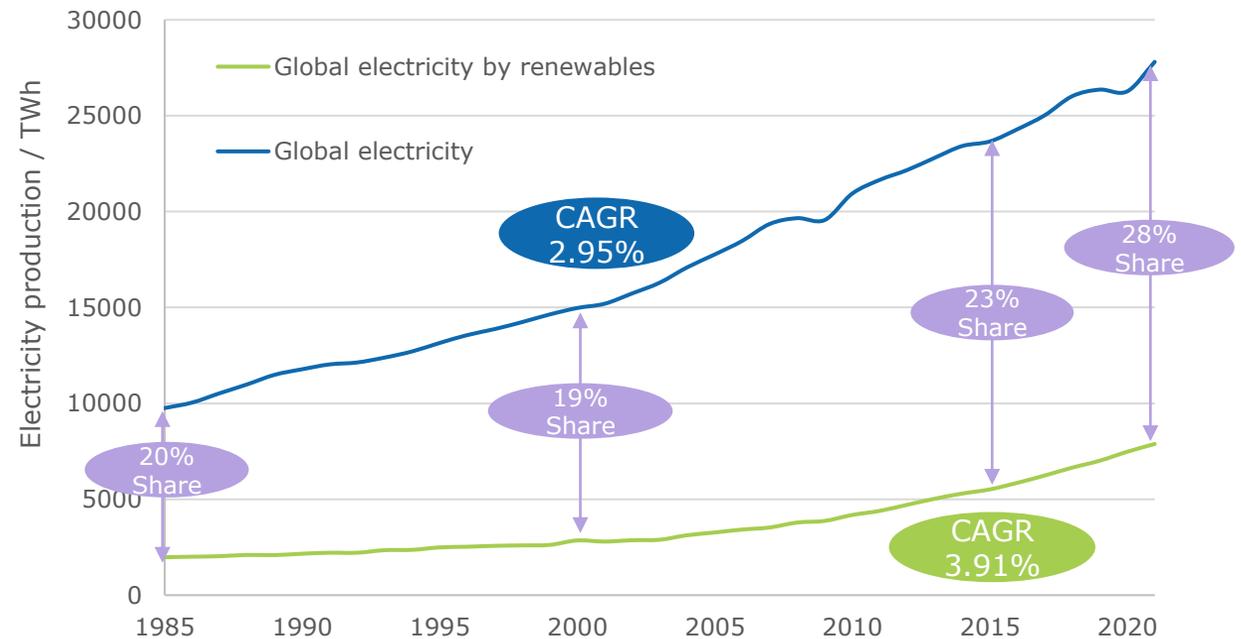
Merck KGaA, Darmstadt, Germany



MERCK

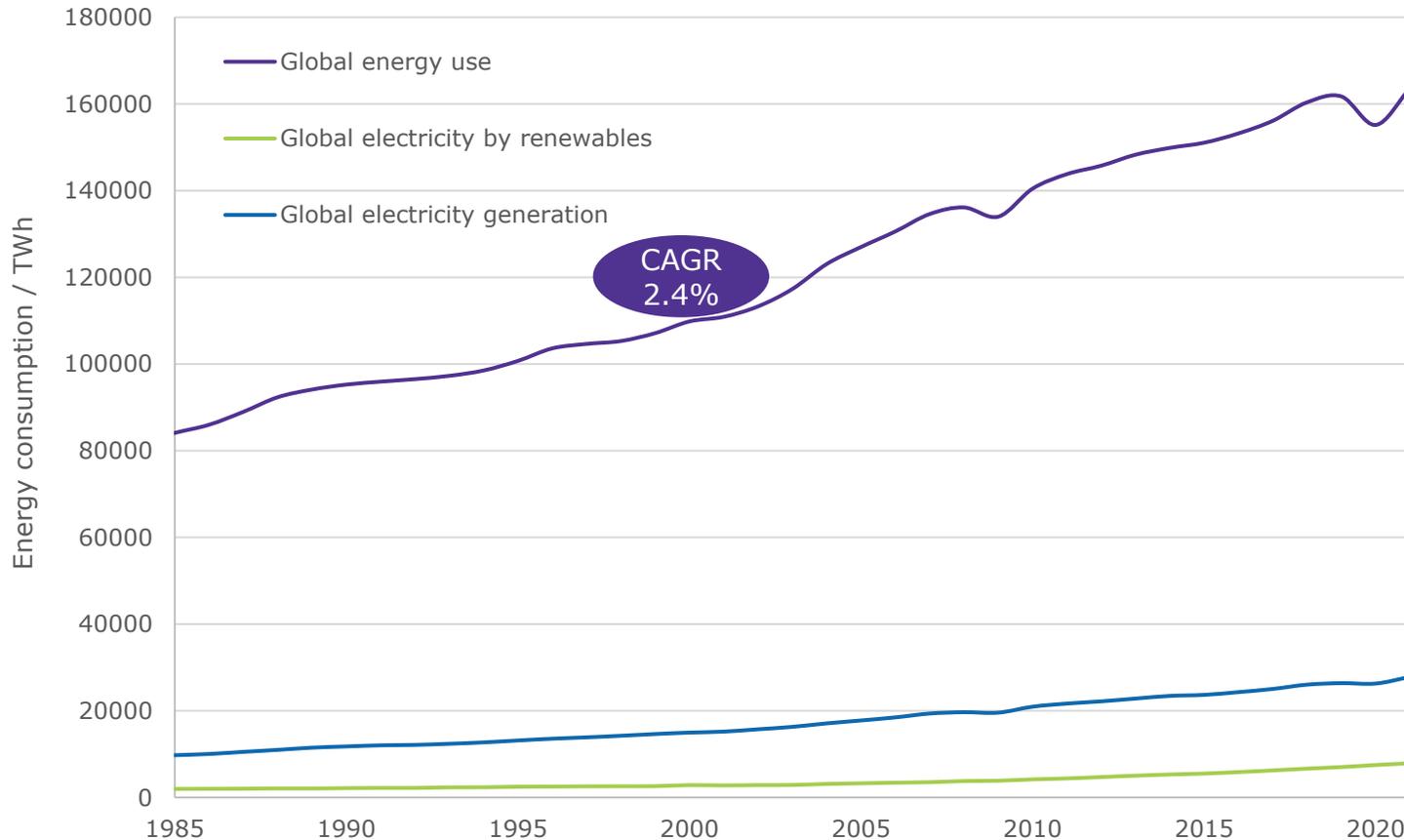
Renewable energy is on the rise!

- Global electricity generation* keeps rapidly increasing
- Share by renewables increases over time
- Doubling of renewable electricity generation between 2010 and 2020 by huge drive in wind and solar



*Source: Our world in data

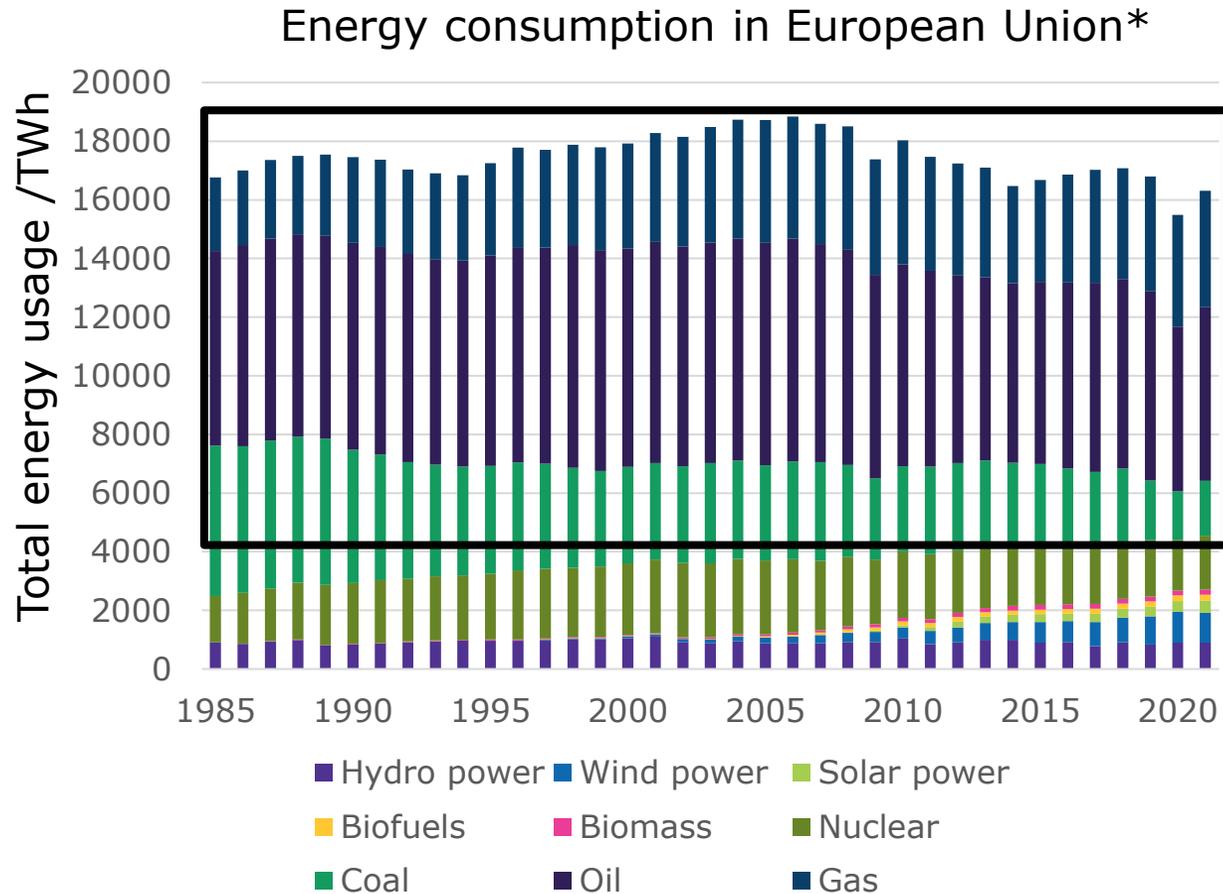
Mother Earth we have an energy problem...



*Source: Our world in data

- Energy usage **increased by ~40000 TWh** every 20 years ("CAGR" 2.4 %/a)
- Share of electricity in global energy usage is ~20%
- Globally we produced **~8000 TWh by renewables** in 2021 But we **consumed ~160000 TWh** total energy in 2021!
- Electricity generated by renewables is outpaced by "energy hunger"

Let's take a look at the European scale...



*<https://globalenergymonitor.org/>

- **Energy consumption** in European Union **stays flat** over 46 years (energy efficiency, outsourcing)
- Share of renewables in European Union are ~15%
- **Oil and Gas make up ~60%** due to traffic, heating and industry

Our ambition is to completely replace this by renewables

...and conclude our strategies to achieve 100% renewables

Analysis of European energy mix

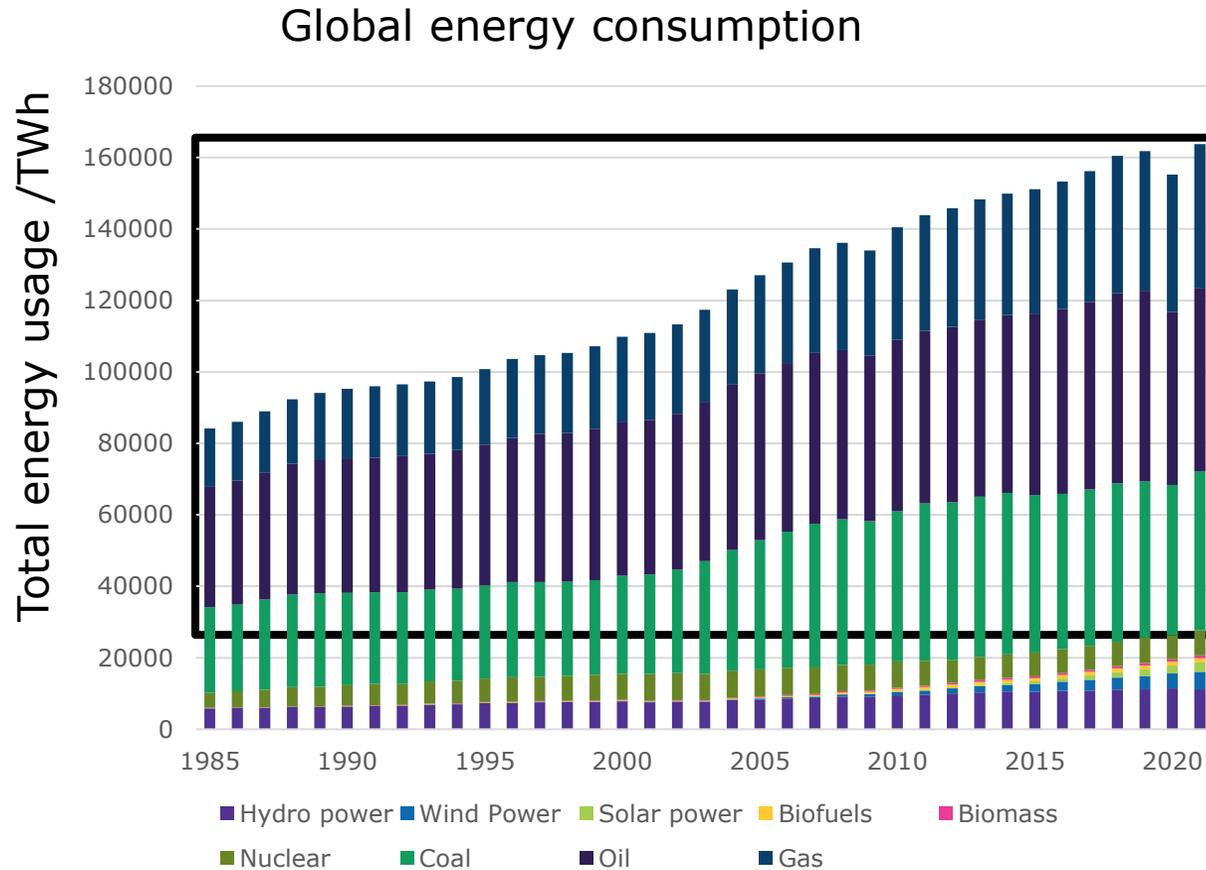
Energy type	Share 2021*	Additional capacity needed to 100%	
Hydro	5,5 %	4600 GW	= 2000 Hoover Dams
Wind	6,3 %	3800 GW	= 17000 Wind Parks
Solar	2,6 %	6200 GW	= 31000 km ² Solar
Biomass	1,1 %		
Biofuels	1,2 %		
Nuclear	11,3 %	1400 GW	= 1350 Nuclear power plants
Coal	11,5 %		
Oil	36,3 %		
Gas	24,3 %		

Solar and Wind Fit to sealed area of 77300 km²**

*<https://globalenergymonitor.org/>

**<https://www.eea.europa.eu/data-and-maps/dashboards/imperviousness-in-europe>

Let's take a look at the global scale...



- **Energy consumption** globally steadily rises
- Share of renewables in globally are ~11%
- **Oil and Gas make up ~56%** due to traffic, heating and industry

Our ambition is to completely replace this by renewables

...and conclude our strategies to achieve 100% renewables

Analysis of global energy mix

Energy type	Share 2021*	Additional capacity needed to 100%	
Hydro	6,8 %	~18000 GW	= 20000 Hoover Dams
Wind	3,0 %	~27500 GW	= 125000 Wind Parks
Solar	1,7 %	~50000 GW	= ~250000 km ² Solar
Biomass	0,5 %		
Biofuels	0,7 %		
Nuclear	4,3 %	9400 GW	= 8950 Nuclear power plants
Coal	27,2 %		
Oil	31,3 %		
Gas	24,7 %		

Solar and Wind
Fit to sealed
area of 500000
km^{2**}

*<https://globalenergymonitor.org/>

**DOI:[10.1016/j.landurbplan.2008.10.011](https://doi.org/10.1016/j.landurbplan.2008.10.011)

Cities and urban areas **consume**
75% of the total energy demand!

We have a long way to go!

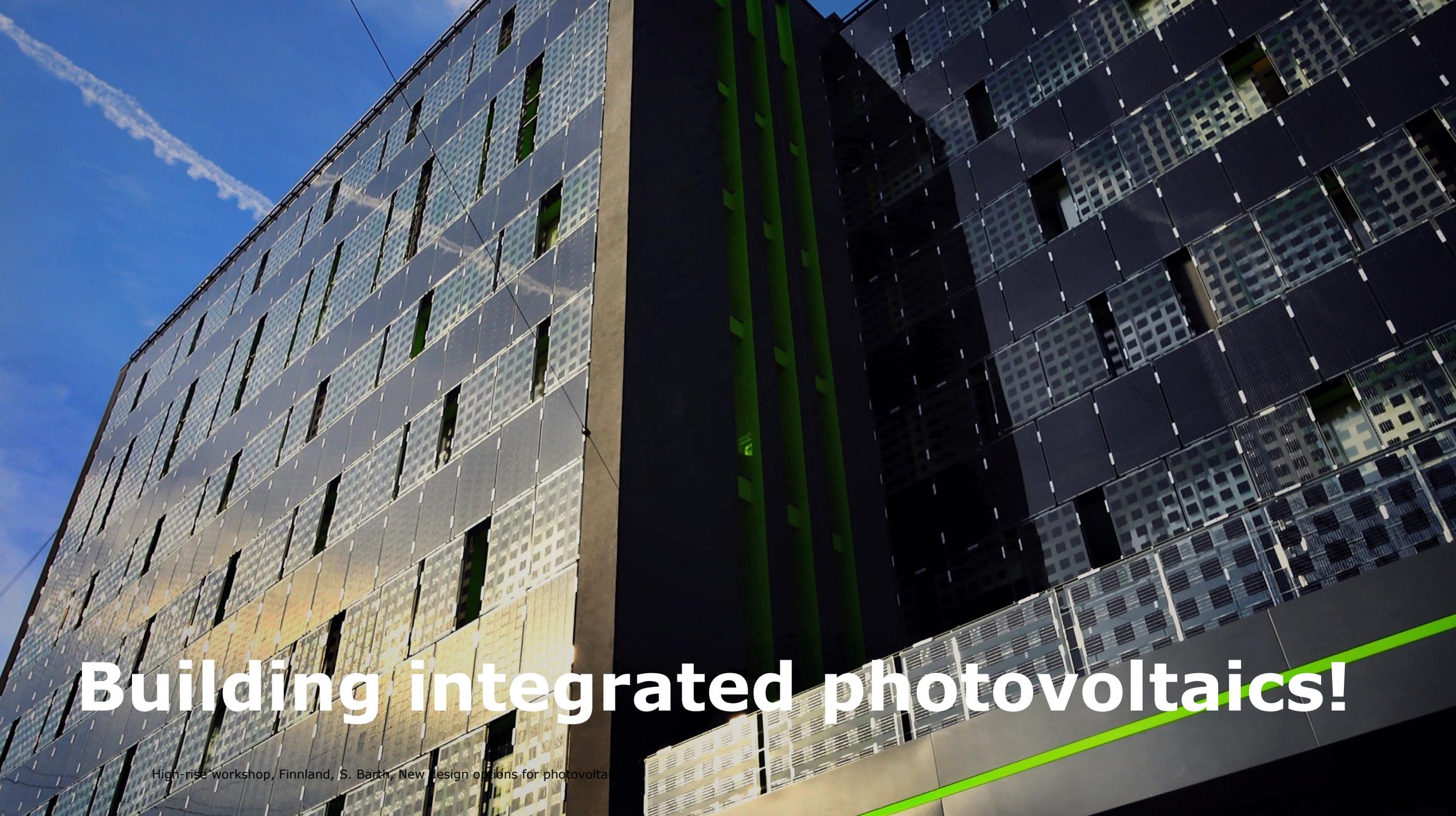


The solution?

High-rise workshop, Finland, S. Barth, New design options for photovoltaics



Not enough space...
Not possible in cities...



Building integrated photovoltaics!

High-rise workshop, Finland, S. Barth, New design options for photovoltaics

A dark, futuristic cityscape at night. The foreground is a flat, grid-patterned floor that recedes into the distance. In the background, a dense cluster of tall, dark skyscrapers rises against a dark sky. Some windows are illuminated, and a bright light source, possibly the moon, is visible in the sky. The overall atmosphere is dark and mysterious.

**Will we live in „dark cities“ with
all black facades?**

Part of the solution: Colored Photovoltaics for facades



Rendering of Leipziger Institut für Meteorologie – ©PEG Architekten



Colored solar installation by Sunovation – ©Sunovation

High-rise workshop, Finland, S. Barth, New design options for photovoltaics

SUNOVATION



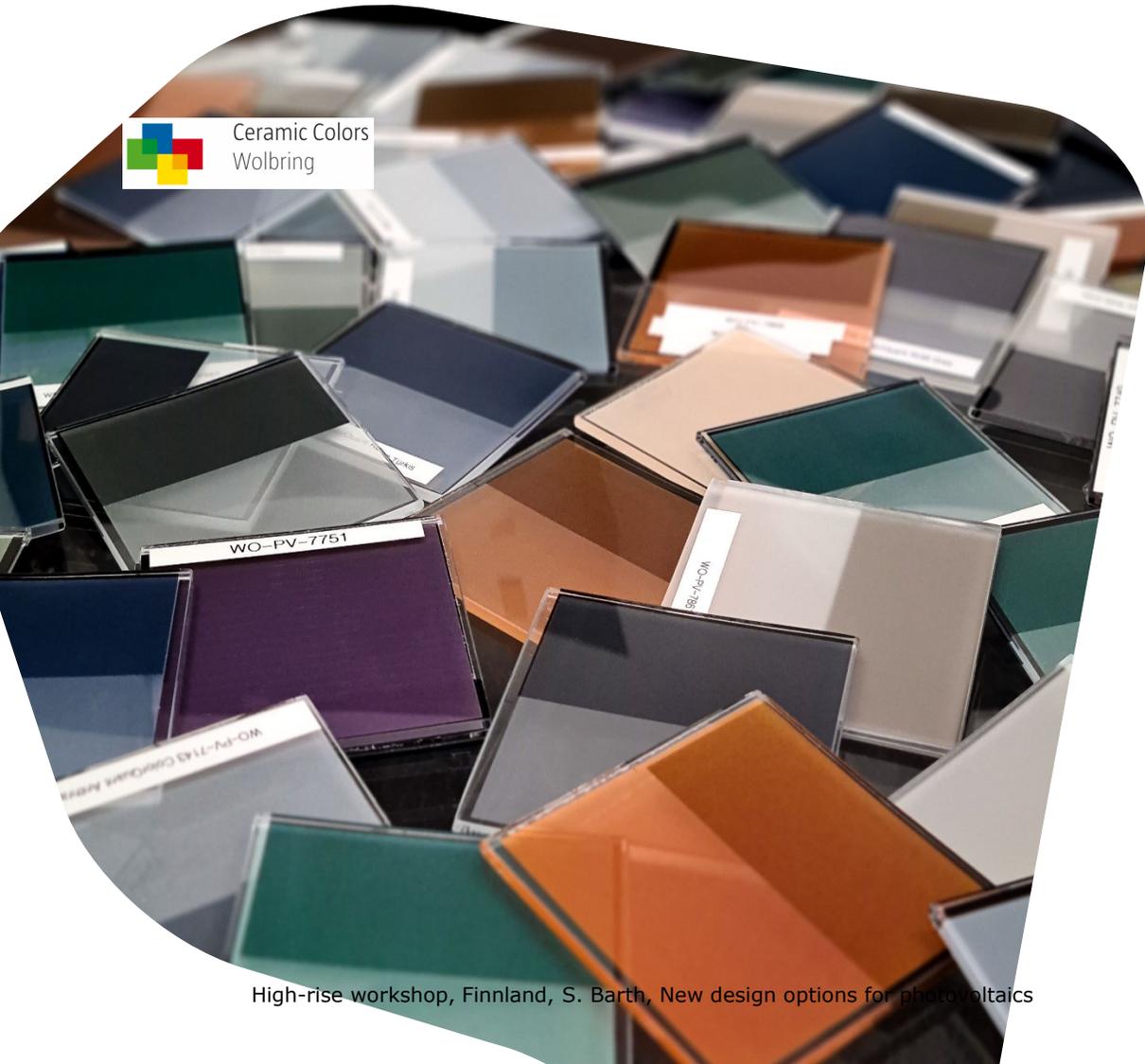
Test installation at Sunovation HQ showing color range – @Sunovation



Golden solar installation with Ertex solar modules - @clevergie

High-rise workshop, Finland, S. Barth, New design options for photovoltaics

Coloring via interference pigments at a glance



- Combining the **low power loss** of dielectric coatings with the **flexibility** of a printing process
- **Tailor made, bright colors** and customized solar module sizes possible
- High flexibility and **reproducibility** of colors
- Solar module **efficiency is retained at 80-95%** depending on the color
- Application of the ceramic paste is possible via screen printing, R2R or spray coating on glass (industrial standard processes)
- ColorQuant™ is applied as a thin ceramic layer (**~35 µm**) before the glass hardening step to ensure **best in class reliability and stability**

Efficient and durable coloring has its challenges

Organic coloring



Degradation!



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Inorganic coloring

Interference

Absorbing pigments

Inefficient

- Light blocking
- Toxic elements
- Dull colors

Dielectric stacks

Complex

- Gas phase process
- Expensive
- Light angle sensitive
- Stability

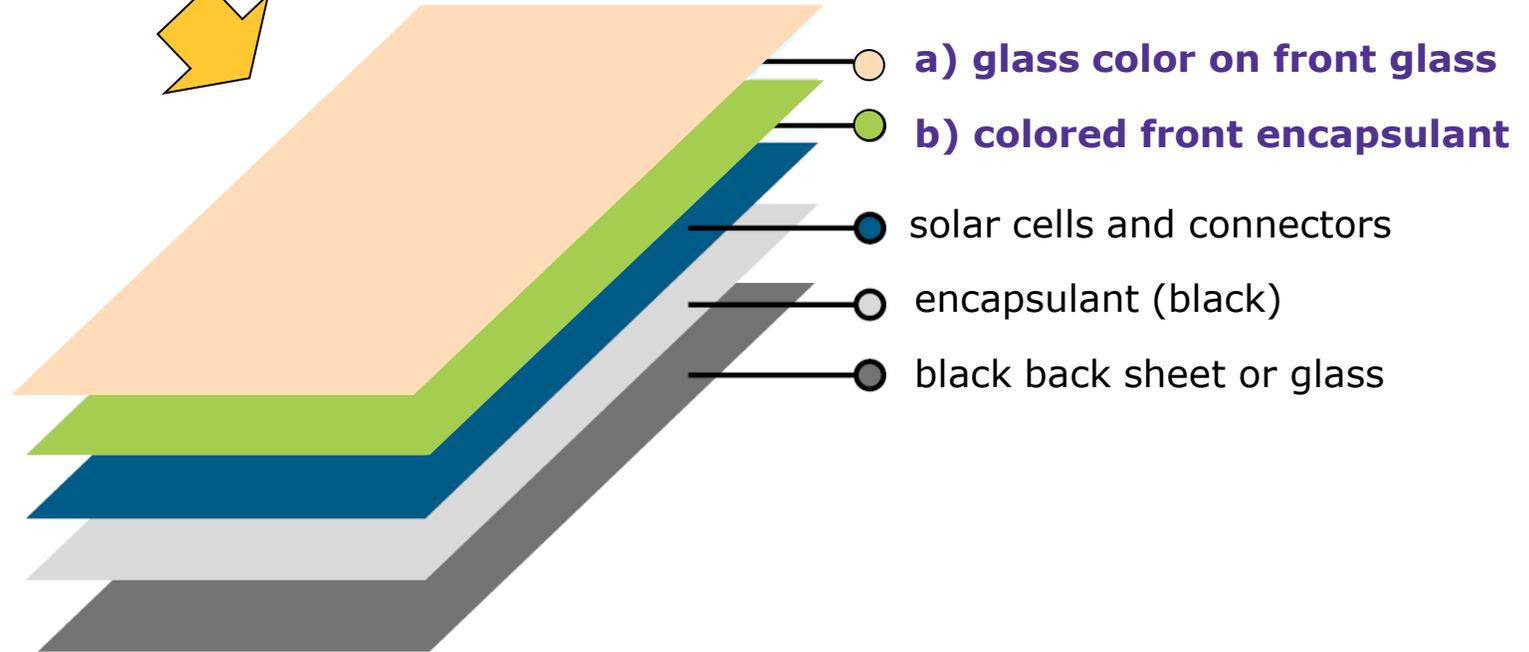
ColorQuant™ photonic pigments

Highly purified and validated colors to

- ensure stability of solar performance
- long lifetime of color performance

Different concepts: How colors can be integrated

Front / light



Coating Basics

- Water-soluble, **environmental friendly** screen-printing paste
- No hazardous labelling needed based on EC directives or respective national laws
- Designed for the Float glass tempering process
 - Glass temperature 600–640 °C
 - Application on a standard flat glass decoration line
- Very strong and long lasting chemical bond to the glass
- High UV durability
- The system is well suited for lamination on the coating



Application

- Different formats and sizes especially for glass facades possible
 - up to jumbo size 3.21 x 6.00m
- Applicable for building under historical preservation
- Coating is recommended on side 2 (inner side) to prevent environmental influence
- Simple application based on glass industry standards
 - printing, drying, co-firing during hardening process
- Process parameters control is key
 - Wet layer thickness, Viscosity, thinning ratio, firing conditions,...
- Final layer after firing consists only of molten glass and inorganic photonic pigments

 **Main reason for high stability**

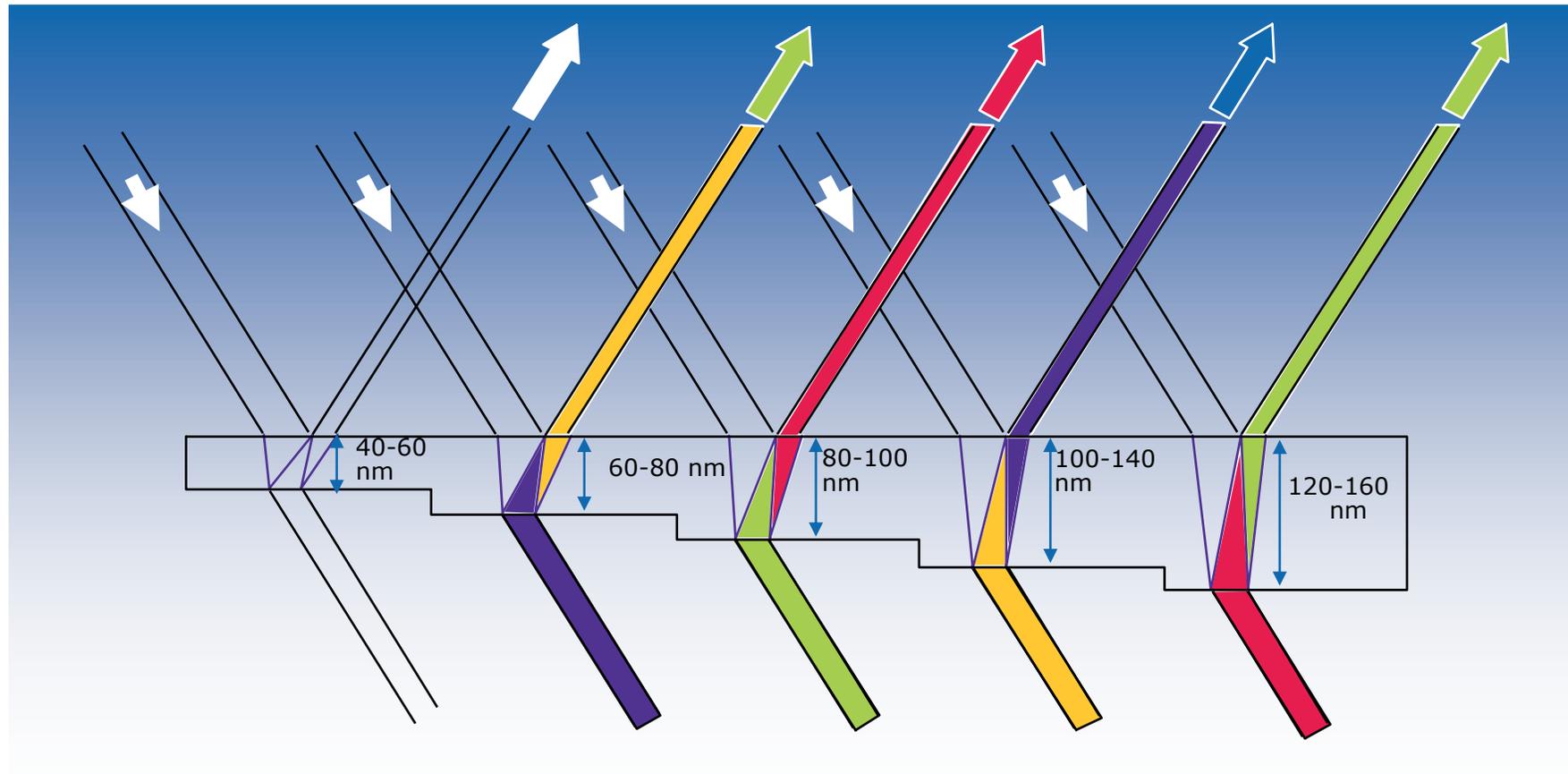


Colored Glass Samples

- Mini module dummy samples available for color impression
- Samples as 10 x 10 cm colored glasses
- Color matching for wide color range possible
- Ceramic color needs to be applied before glass hardening step
- Ceramic color paste in 0,5 kg samples
-



Photonic pigment layers – theoretical background



Selective reflection of light by building photonic layers on transparent pigment platelets

Summary

- The **share of renewables** in our global energy demand **is still small**
- If we want to move to **sustainable, independant energy supply** we need to change the way we are using e.g. solar energy today
- ColorQuant™ allows **revolutionary design for BIPV** and enables a win-win solution for every stakeholder in the value chain
- Combination of the advantages of dielectric layers and printing leads to a very **competitive cost/performance ratio**
- High range of **customized colors** possible while achieving a **high chroma** / color impression
- ColorQuant™ can be **easily integrated** into solar module manufacturing and sample process-flow is also easy and fast
- For more information visit us at: <https://colorquant.ceramic-colors.de/de/>

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