Organic Photovoltaics: the breakthrough in new markets like agrivoltaics for flexible and lightweight PV

Thomas Kolbusch, Vice President

07/01/2023

MEMBER OF ATH

Agenda

1. Introduction
2. 3rd Gen solar technology
3. Agrivoltaics
4. Today`s equipment
5. Summary

1.

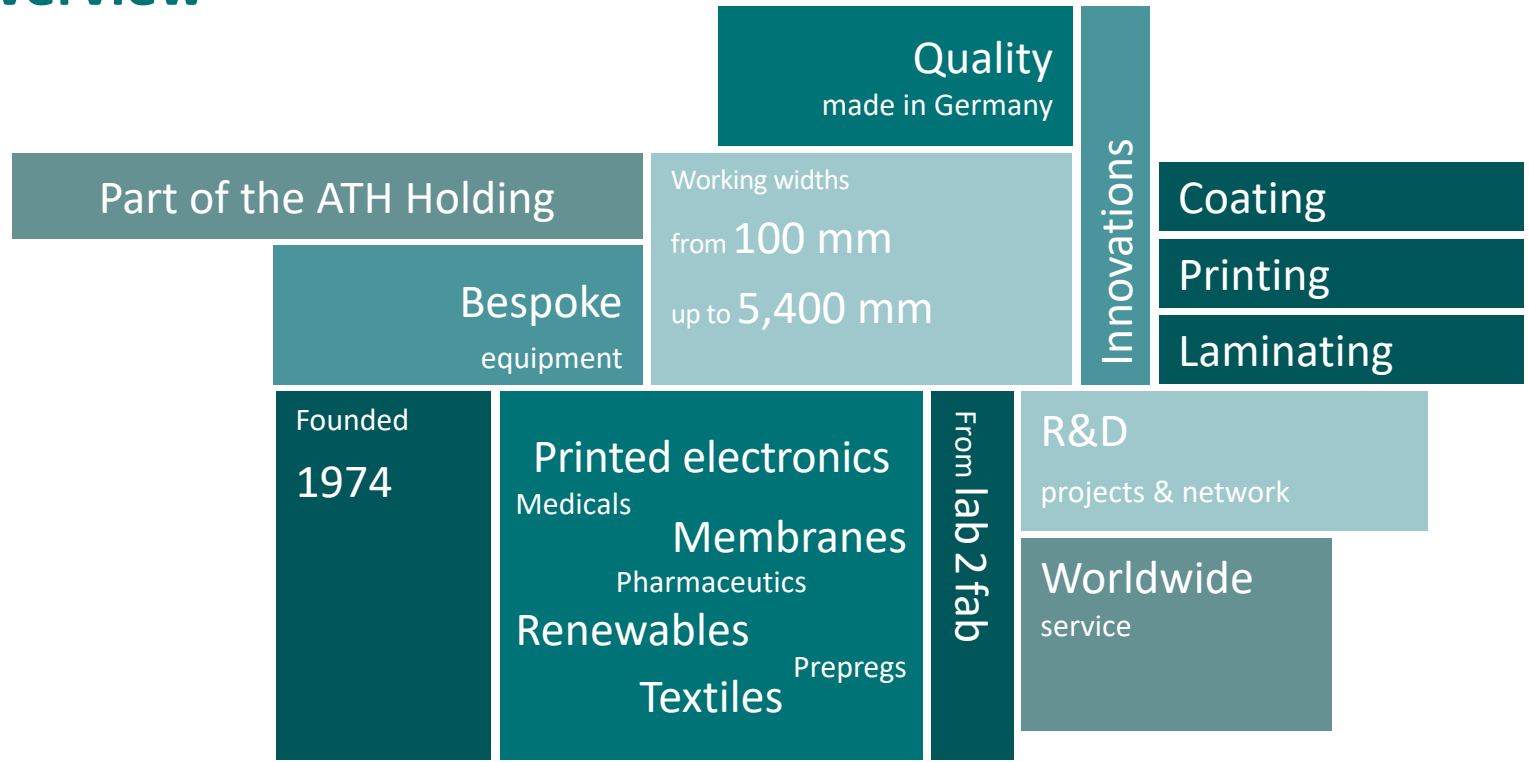
Introduction

Thomas Kolbusch, Director Sales, Marketing, Technology, VP

Thomas
Kolbusch

COATEMA Coating
Machinery GmbH

Overview


Quality
made in Germany
Innovations
Part of the ATH Holding
Working widths
from 100 mm
up to 5,400 mm
Coating
Printing
Laminating
Bespoke
equipment
Founded
1974
Printed electronics
Medicals
Membranes
Pharmaceutics
Renewables
Prepregs
Textiles
From lab 2 fab
R&D
projects & network
Worldwide
service

Group of companies

ALTONAER
TECHNOLOGIE
HOLDING

KROENERT

- ✓ Founded 1903
- ✓ Approx. 200 employees
- ✓ Located in Hamburg

DRYTEC

- ✓ Founded 1995
- ✓ Approx. 50 employees
- ✓ Located in Norderstedt

Coatema®
Coating Machinery GmbH

- ✓ Founded 1974
- ✓ Approx. 50 employees
- ✓ Located in Dormagen

Vision – from lab 2 fab

Lab → Pilot → Production

Coatema equipment platform strategy for lab 2 fab

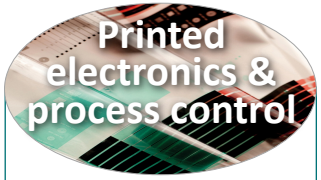
Coatema focus areas

- Green Hydrogen
- Fuel Cells
- Batteries
- Solar

- Sustainability
- Digital fabrication
- Printed electronics
- The next thing

R&D customers

R&D projects overview 2022

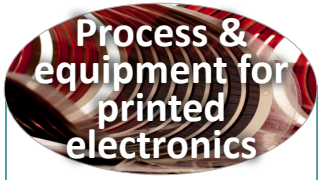


REAL NANO

In-line and real-time digital nano-characterization for flexible organic electronics

Oled Solar

Advanced production for opto electronics towards industry 4.0

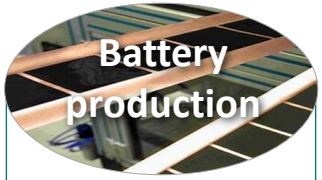


EffiLayers

R2R process optimization of organic photovoltaic cells

ENP

Development of near-field electro hydrodynamic nanowire printing



IDEEL

Implementation of laser drying processes for lithium-ion battery production

SOLiD

R2R process optimization for solid state batteries

pepLAT

Plasmonically enhanced photocatalysis for wastewater treatment

RetroWin

R2R Process and machinery development for retrofit window films for lower production costs

GREEN SENSE

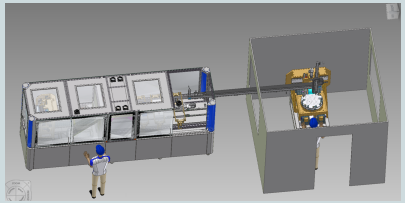
Sustainable paper-based printed electronics and biosensing platform

FLEX FUNCTION 2 SUSTAIN

Creating an open-innovation testbed for sustainable packaging

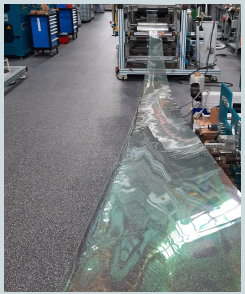
Highlights of R&D projects 2021 – 2022

PEP LAT

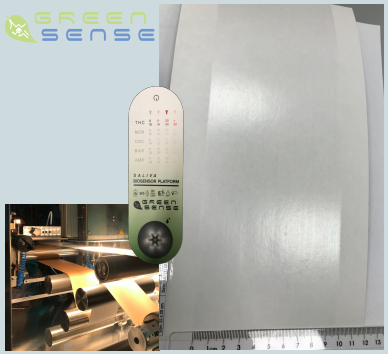


FLEX FUNCTION 2 SUSTAIN

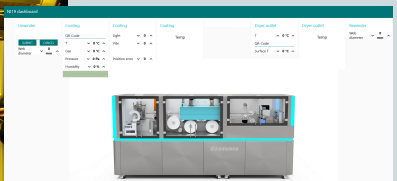
RetroWin



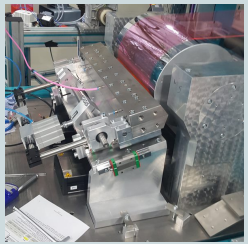
GREEN SENSE



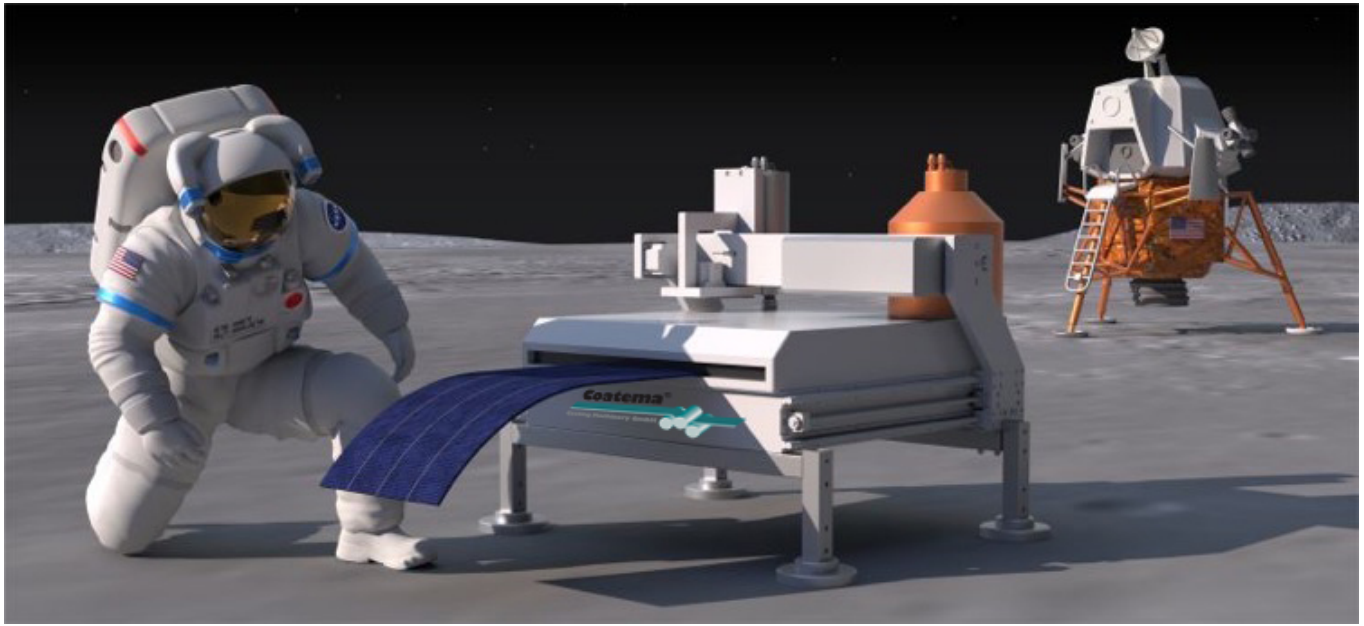
Oled Solar



IDEEL



The vision from NASA – perovskite on the moon



What would it take to manufacture Perovskite Solar Cells in space? | ACS Energy Letters

Source: Author: Lindsey Mc Millon-Brown

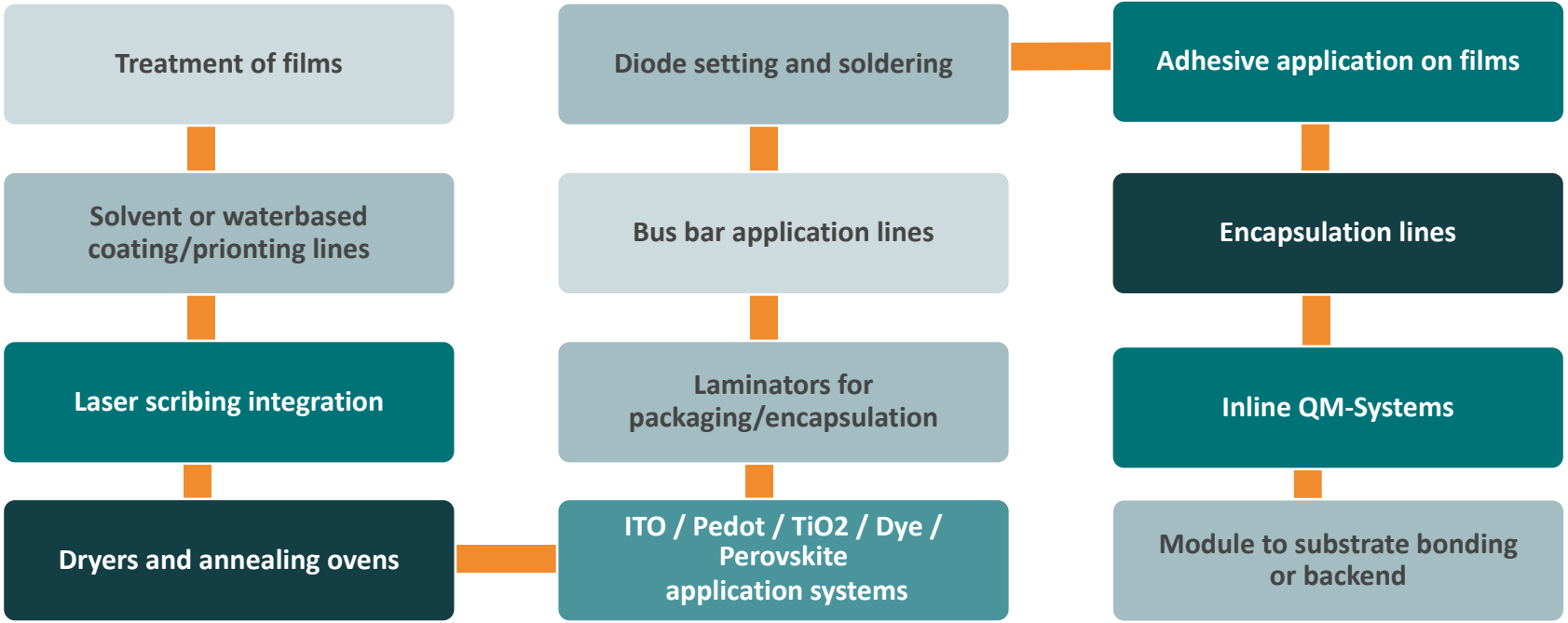
2.

3rd Gen PV

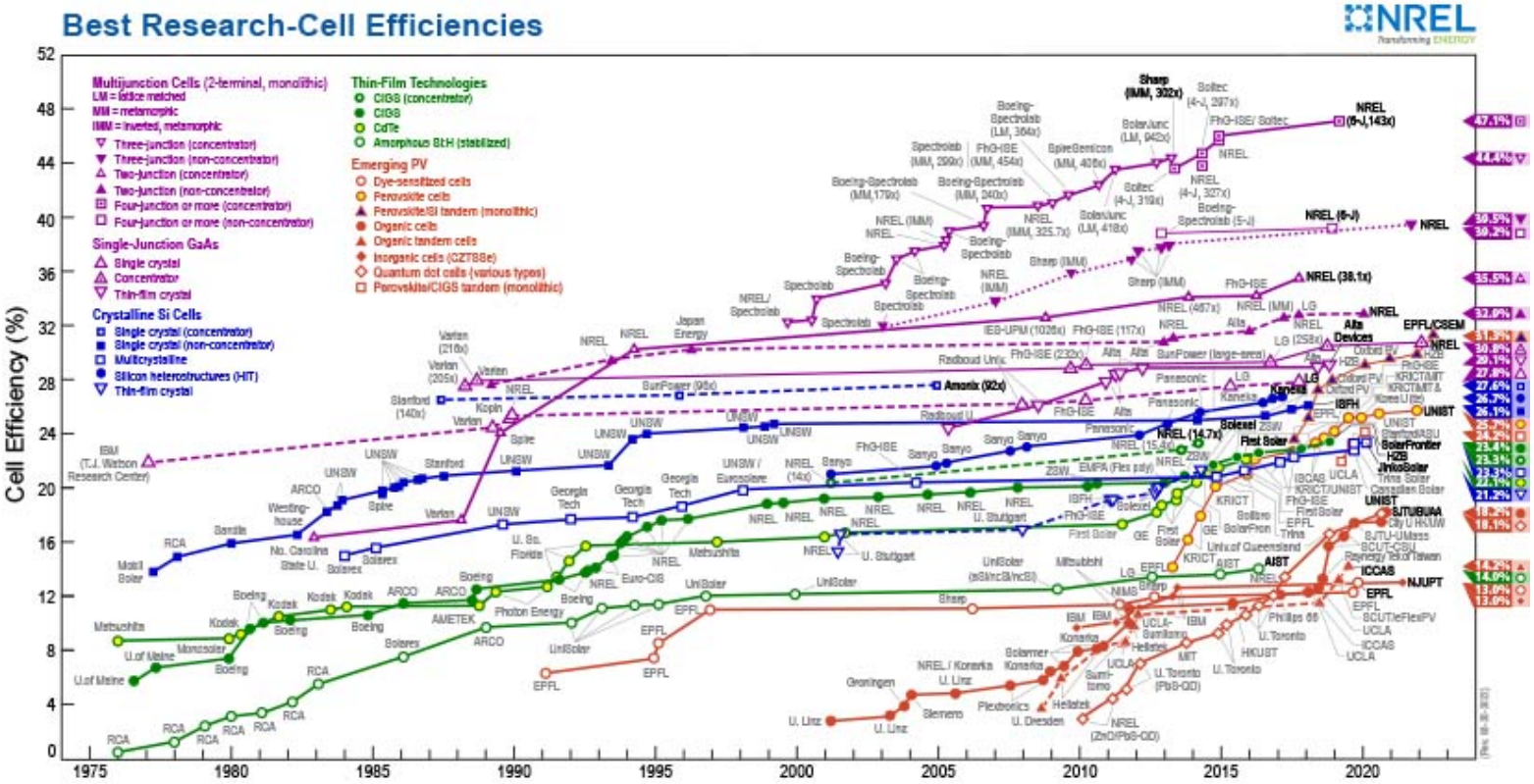
Overview of the different solar cell types

Technology	Advantage	Challenge
a-Si	Excellent for BIPV due to a prooven life time longer than 10 years	Light-induced degradation, Efficiency, Cost for production equipment
CIS/CIGS	Low cost, Efficiency, R2R processes	Availability of Indium
CdTe	Efficiency, life time, stability, well developed, economical production costs	Heavy metal Cadmium
DSSC	low weight, R2R, good performance in diffuse light conditions,real flexible, low cost production methods	Device stability, life time, efficiency
Polymer	Lightweight, flexible, low cost coating or printing methods	Efficiency, Device stability, life time
Perovskite	Lightweight, high efficiency from the beginning	Lead layer and lifetime

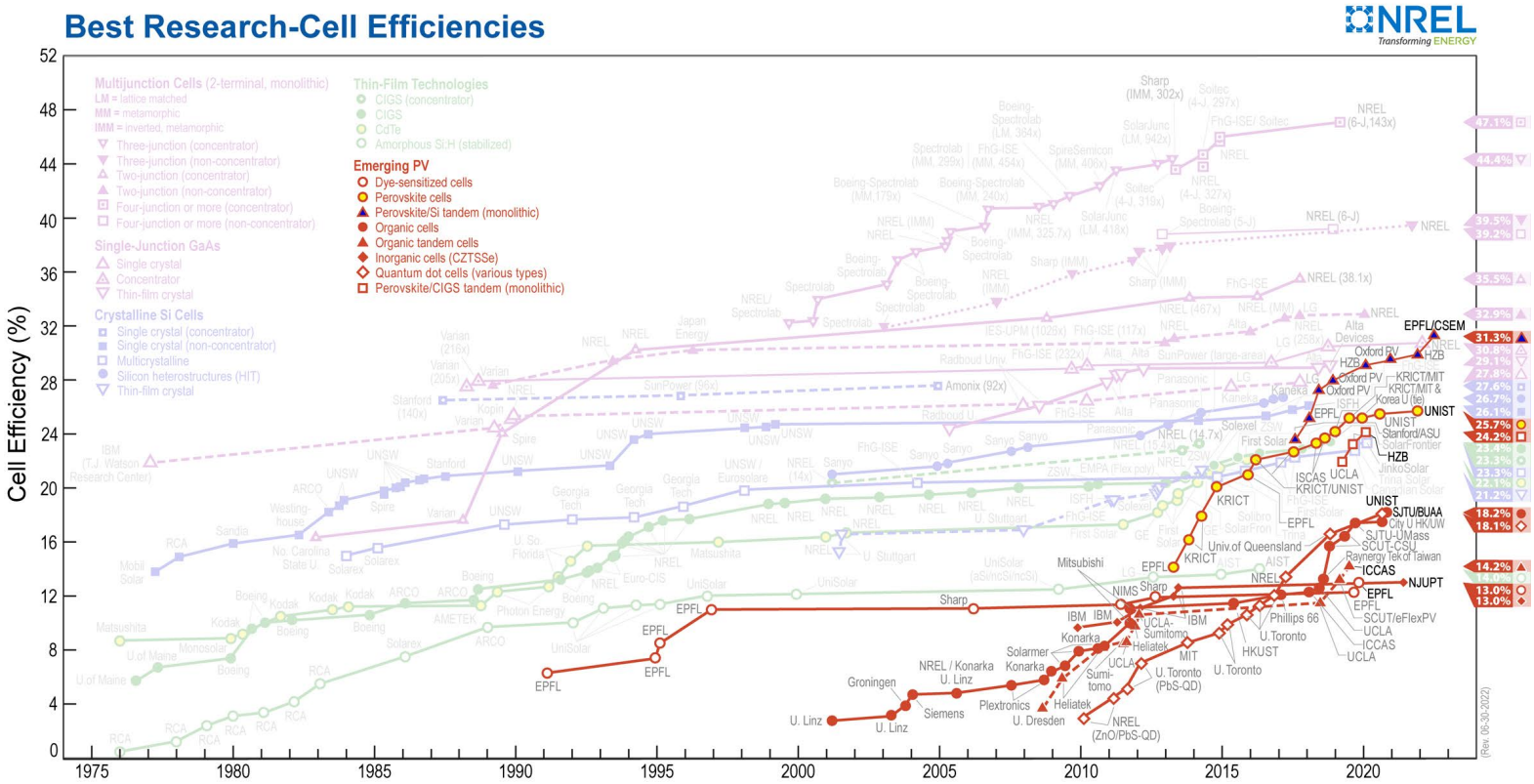
Production chain modules



Cell efficiency

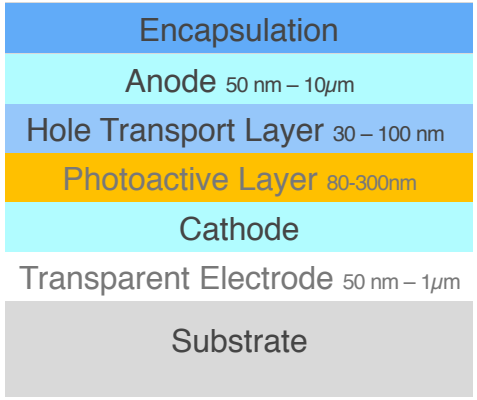


Cell efficiency for 3rd Gen solar



OPV USP

- ✓ Flexible
- ✓ Low cost
- ✓ High volume R2R processes
- ✓ Thin
- ✓ Light weight
- ✓ Versatile applications
- ✓ Green mobile power
- ✓ Sexy



Glass or barrier film

Solution-processed metals (such as Silver)

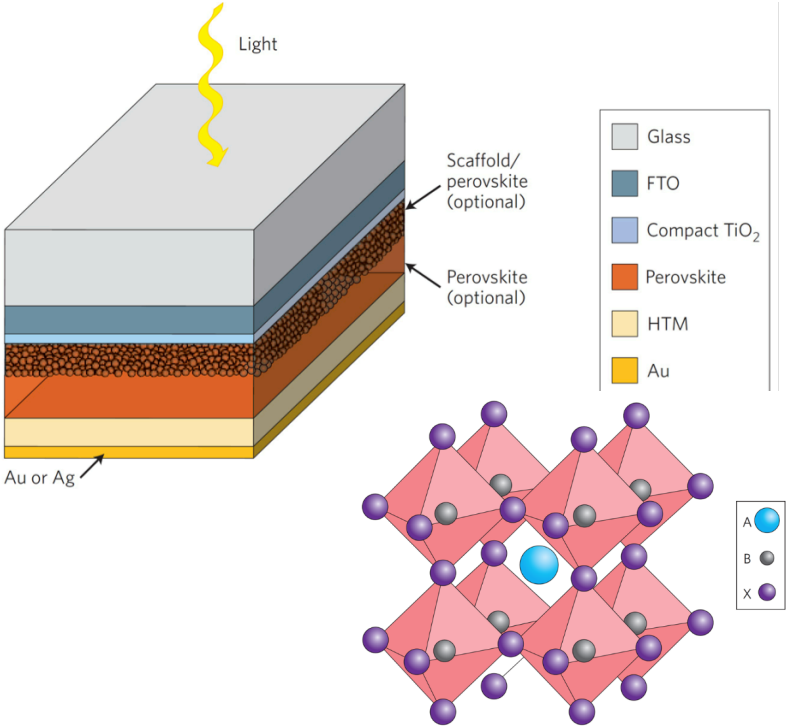
Solution-processed ZnOx

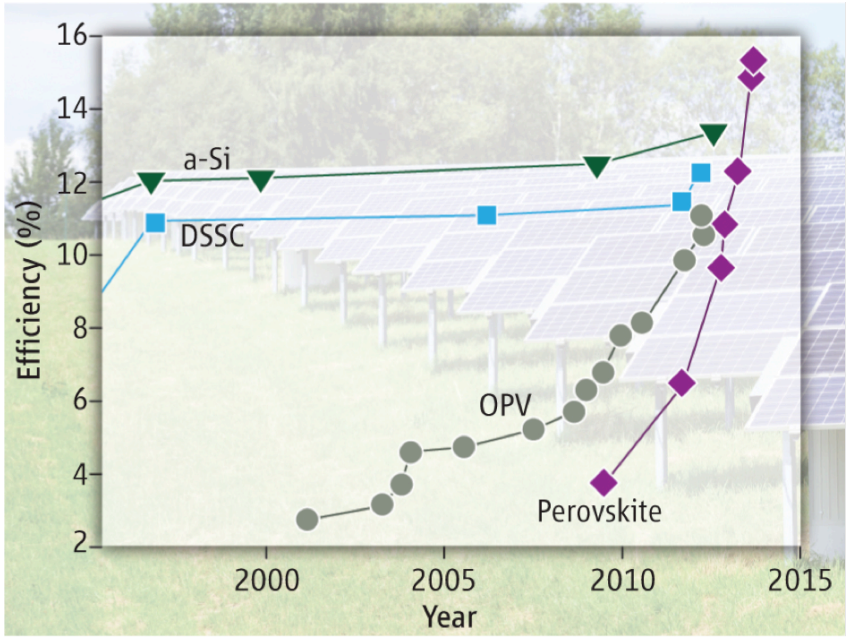
Transparent ITO or metal oxides
Plastic film (i.e. PET, PEN)

Conductive solution with
- ✓ Conductive polymer
- ✓ Matrix material
- ✓ Additives
- ✓ Co-solvents

Bulk heterojunction with
- ✓ Polymer p-type (P3HT)
- ✓ Fullerene n-type (C60 PCBM)
- ✓ Aromatic solvents

Perovskite, 3rd gen solar



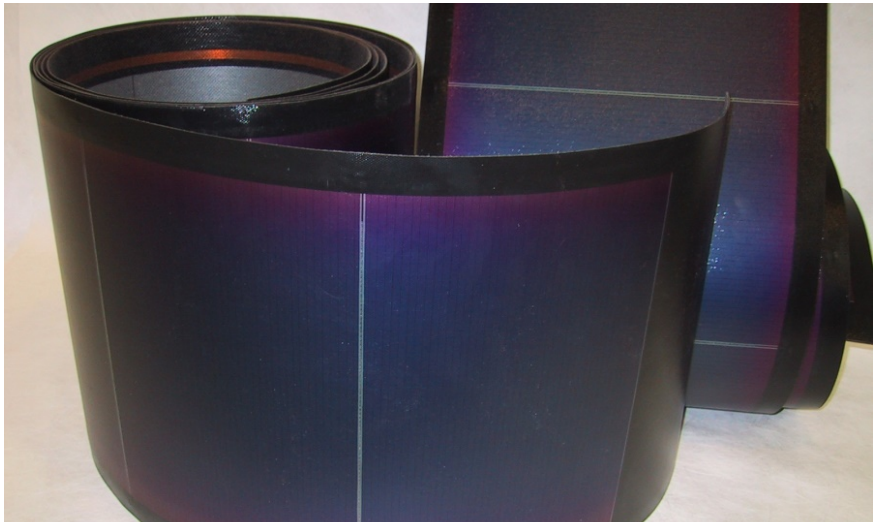


Source: Image Credit: Martin Green et al / Nature Photonics

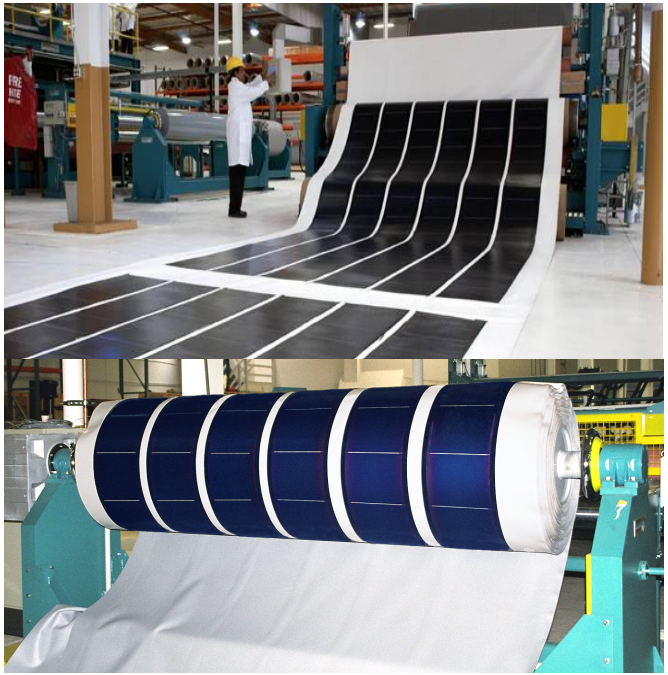
Coatema Core Technologies in solar technologies

Dye sensitized solar cell (DSSC)	Organic photovoltaics (OPV)	Perovskite	Slot die coating/ Printing processes
Process inline control	Drying/ Anealing	Encapsulation	Backend

1999



Solar Integrated Technologies strategic partnership with Uni-Solar, provides SIT with up to 30MW annually of flexible Photovoltaic cells



1999 – flexible PV on roofing membrane

Production facility in Los Angeles

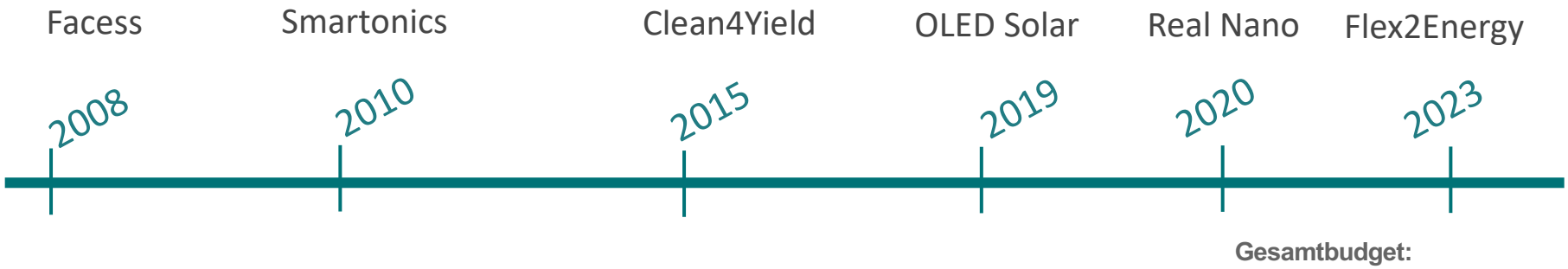
Flexible PV on roofing membrane

1999 – flexible PV on roofing membrane

Solar cell projects at Coatema

2005 – 2022

Developing 3rd Gen PV at Coatema



✓ 3 BMWF Projects with Ruhr University Bochum and ILT: FlexLAS – Photonflex – Effilayers

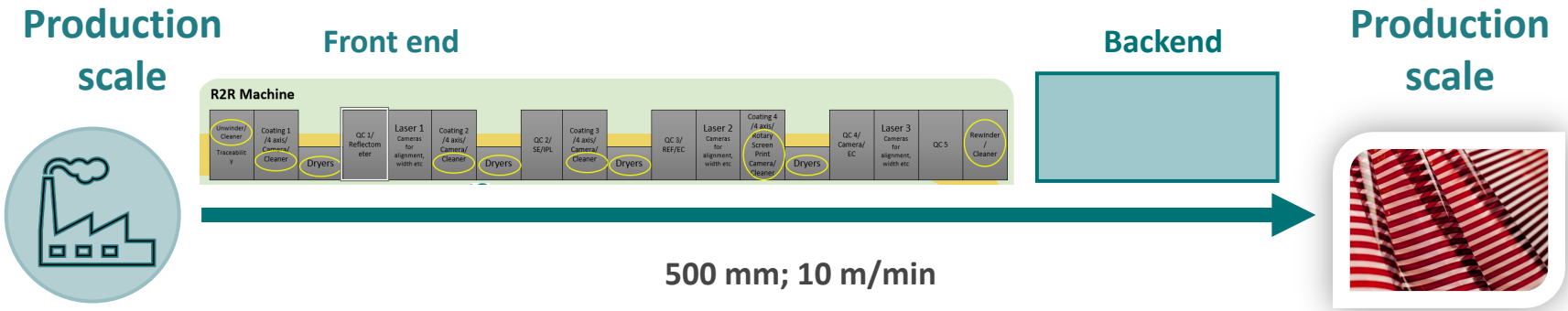
✓ 1 REGAC project – LS09 Registration improvement on the MAXI Line at VTT

<u>OPV equipment outside of funded projects</u>

G24i, Solarpower, CSEM, VTT-LS09 MAXILINE, UNSW, CSRIO

CSEM, Eight Nineteen, Heliatek

Proof of production process in Greece – Flex2Energy



Process integration as industrial standard

- ✓ Integration into a single R2R process suitable for the production of the OPV modules
- ✓ Integration of backend

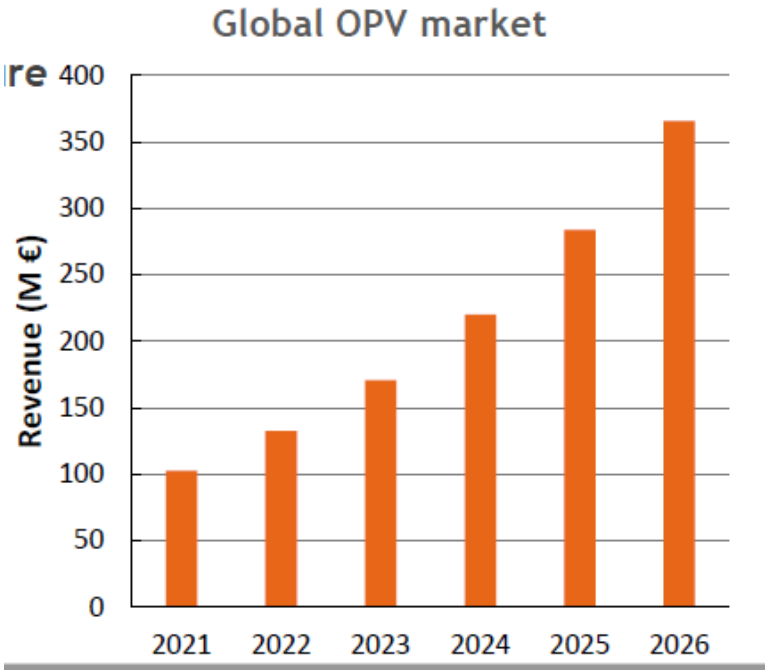
Demonstration and evaluation

- ✓ Production of 3rd Gen OPV
- ✓ Licensing the overall giga fab concept

Market opportunities and volume

Global OPV Market is estimated to reach up to 366 M$ by 2026 and there are few key-players that open the market today

- ✓ CSEM, sunew, Brasil
- ✓ Rayenergy, PRC
- ✓ Heliatek, Germany
- ✓ ARMOR, France



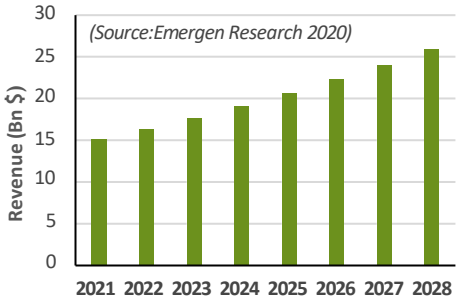
3.

What means Agrivoltaics

Global Agriculture Market will be 13 Trillion $ in 2025

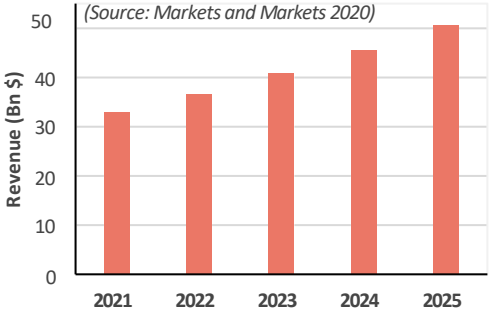
- ✓ About 56 B€ were invested in Agriculture Capital in EU
- ✓ Increasing World Population increases the demand for food and land area

Smart Farming Market



Smart Farming Market will reach 20,6B$ by 2025 & 26B$ by 2028

Global Greenhouse Market



Greenhouse Market will reach 50,6B$ by 2025

What is the idea

Saving our planet

ENERGY

Smart greenhouses

Land use and resource efficiency

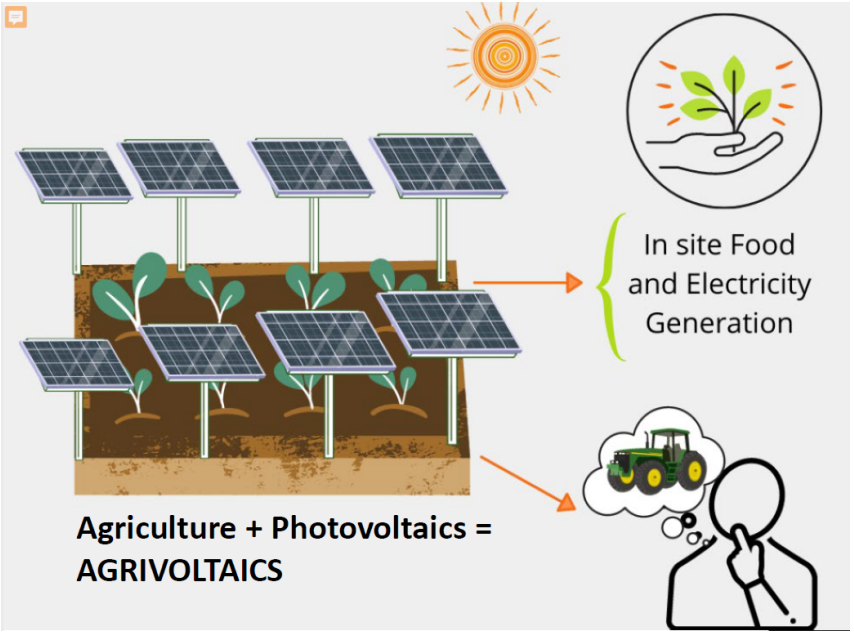
Dual income

Benefits

- ✓ Lightweight & flexible structure
- ✓ Large-scale production by R2R Printing Process that is less Energy Demanding, Cheaper and Eco-Friendly
- ✓ Free-form design and color uniformity
- ✓ Recycleability

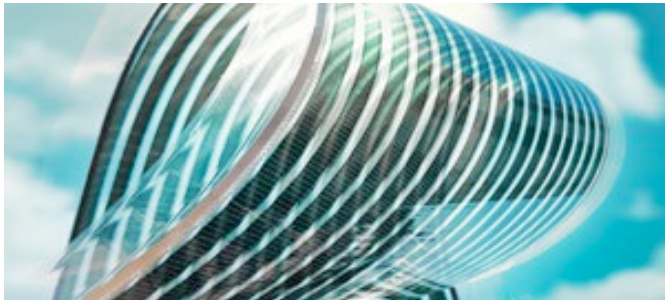
Why is agrivoltaics the future of greenhouse farming

- ✓ The Co-location of OPVs and crops in the same area minimize land impact
- ✓ Clean energy production and at the time increase of crop production by 30%
- ✓ Shading and cooling effect
- ✓ Land and water use efficiency
- ✓ Increase of income of farmers



Innovation – OPV products

- ✓ Highly efficient OPV products easily adaptable in buildings, automotive, agriculture and infrastructure
- ✓ Sophisticated architectures of novel nano-layers from organic semiconductors (electron donors and acceptors), transparent electrodes and inorganic electrodes
- ✓ Can be printed on transparent flexible polymer substrates
- ✓ OPV panels with increased uniformity, power output of **90 W/m²**, high **transparency >60 %** and improved **lifetime >20 years** and unique uniform and homogeneous design



3rd Generation PVs

- ✓ High and tinable optical transparency
- ✓ Lightweight & flexible structure
- ✓ Large-scale production by R2R Printing Process that is less Energy Demanding, Cheaper and Eco-Friendly
- ✓ Free-form design and color uniformity
- ✓ Recycleability

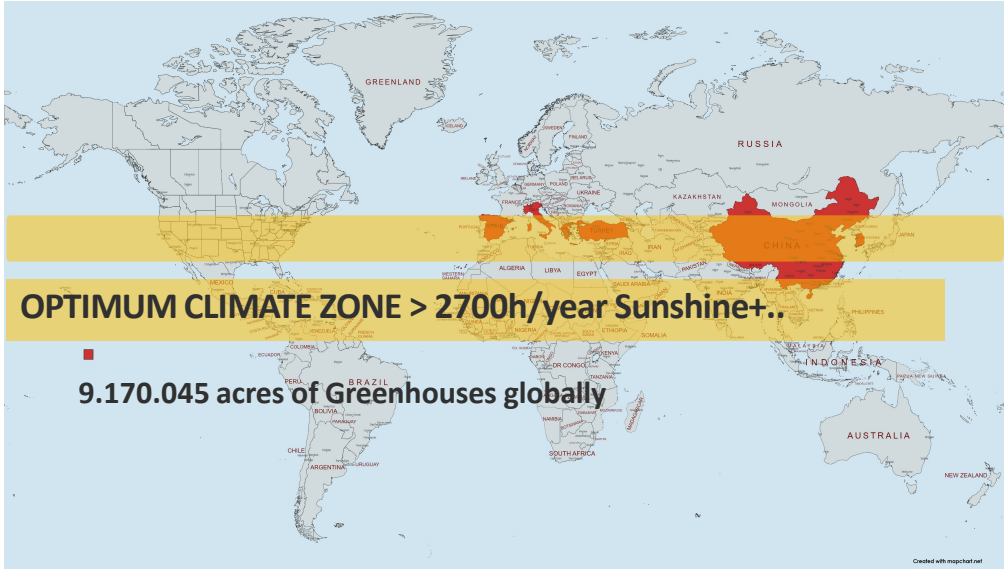
OPV in GREENHOUSES

- ✓ Semi-Transparent OPVs in GHs
- ✓ UV Filter & Shading
- ✓ Increased Crop Production
- ✓ Energy Generation & Production
- ✓ Provide Energy Autonomy
- ✓ Easy Installation on the Plastic & Glass GH without Metal Brackets & Supports

Situation today

Environmental impact and carbon emissions Demand and challenges in Greenhouse sector

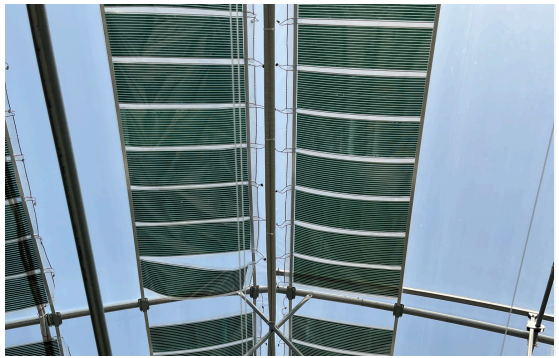
- ✓ **Energy consumption in a greenhouse could reach up to 50% of the total production cost** (e.g. due to large heating/cooling costs in winter/summer
- ✓ Energy is consumed in **heating, cooling and ventilation systems, LED grow light, automations, sensing, distance monitoring, irrigation systems and control systems**
- ✓ **Thermal heating demand represents ~ 80% of the energy consumption**, while electricity the 15%
- ✓ **Indicative average energy consumption for a greenhouse in Spain ranges 30 to 70 kWh/m²**
- ✓ **RES** for facilitating rational and sustainable farming **are necessary**
- ✓ Demand for integration of **new and smart technologies**
- ✓ **Growing need for energy autonomy**



Development of agrivoltaic greenhouses

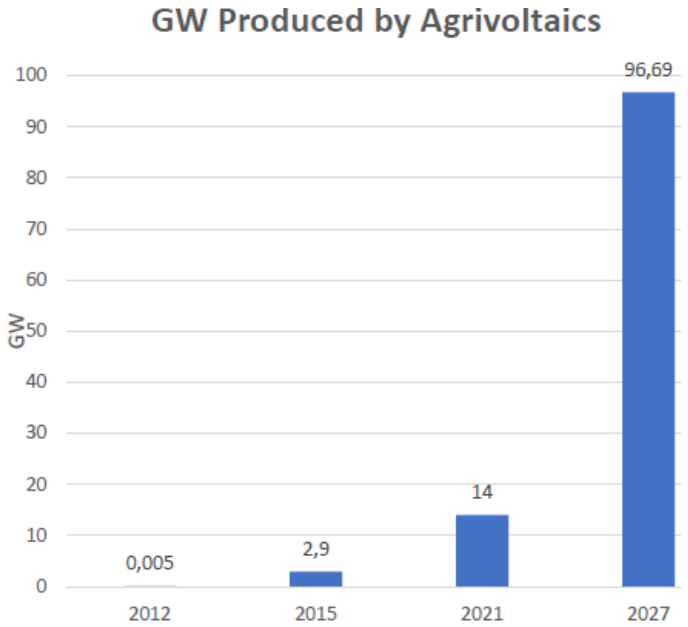




Expected market grow for Agrivoltaics

- ✓ Global installed Agri-PV capacity has increased exponentially from 5 MW in 2012 to 14 GW in 2021 (Expected reach of 97 GW in 2027)
- ✓ The global agrivoltaic market will grow at a CAGR of ~38 % (2022 – 27)
- ✓ Due to rapid climate changes create huge challenges for energy & agriculture worldwide
- ✓ The shift focus toward adopting agrivoltaics to enable the effective use of sunlight for crop growth



Source: MarkNtel 2021

Flex2Energy (start beginning 2023)

- ✓ **Call:** HORIZON-CL5 2022-D3-01-03:Advanced manufacturing of Integrated PV
- ✓ ***Project aim:*** boost Integrated Photovoltaics manufacturing and the reliability
  - ✓ New R2R pilot-to-production line with integrating smart, cognitive and adaptive in-line sensors and actuators for quality control with Artificial Intelligence (AI)-based analysis

FLEX2ENERGY
AUTOMATED MANUFACTURING PRODUCTION LINE FOR IPVS

Partners

The novel idea of Flex2Energy

- ✓ Revolutionize the renovation & construction wave of the EU's building industry (buildings, infrastructure, greenhouses and automotive) of all kinds of uses and locations

  → Implementation of novel IPV products for energy positive building concept (Fig. 1)

- ✓ Spread novel IPV products through the setup of a strong Innovation Clusters Network (ICN) in green buildings agriculture and transportation to form and connect this Value Chain of 40 ICs across Europe (Construction, Architects, Designers, Engineers, Contractors, Suppliers, end users etc.)

- ✓ Demonstrate, evaluate, spread and ultimately replicate the developed innovations

FLEX2ENERGY
AUTOMATED MANUFACTURING PRODUCTION LINE FOR IPVS

Fig. 1. F2E automated Manufacturing line for OPVs and IPV products to open the way for energy positive buildings & to minimize landscape

4.

Today`s equipment for todays 3rd Gen PV

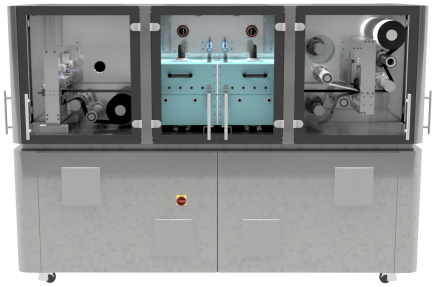
Sheet-to-Sheet (S2S)

Test Solution

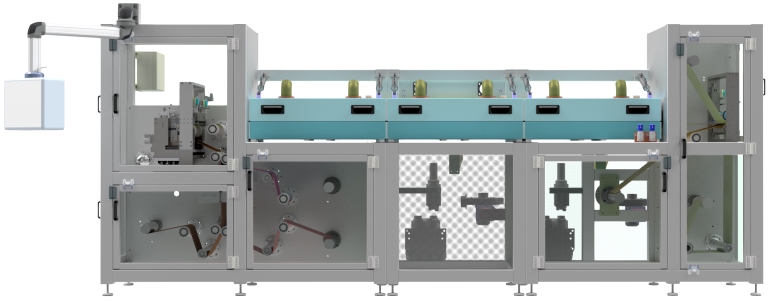
Easycoater

Easycoater Evolution

Roll-to-Roll (R2R) lab systems



Test Solution R2R



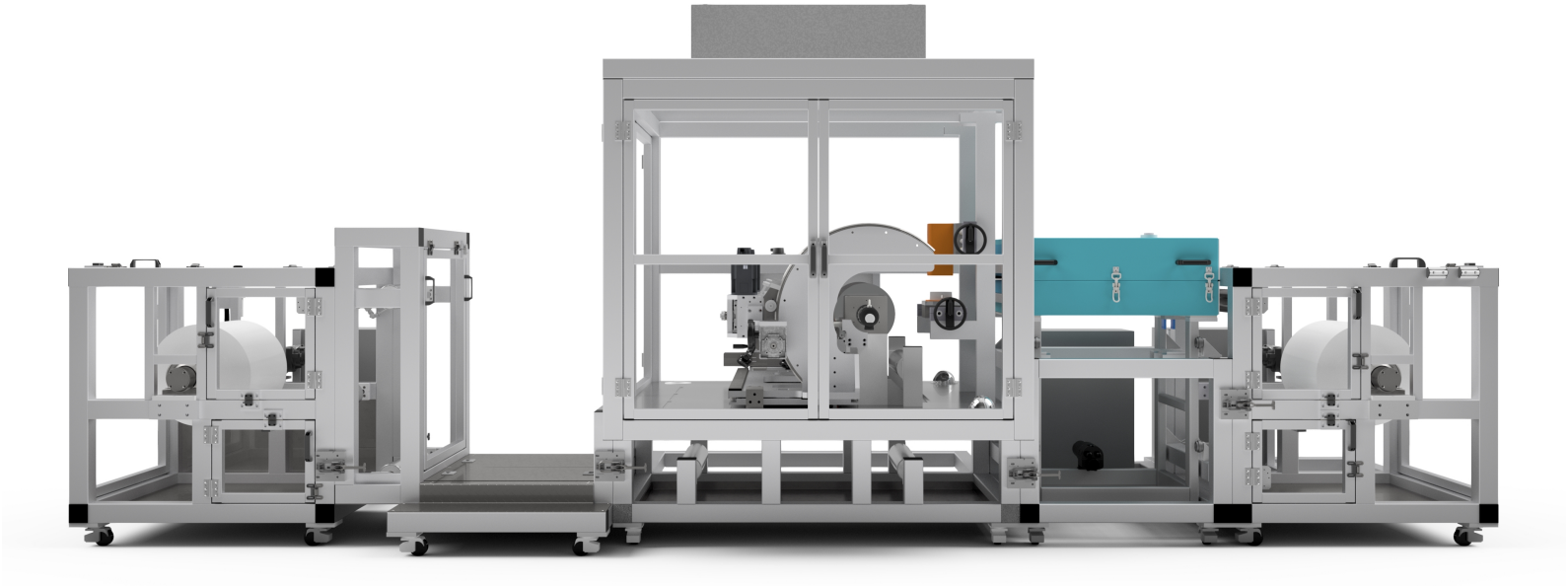
Basecoater R2R

Smartcoater R2R

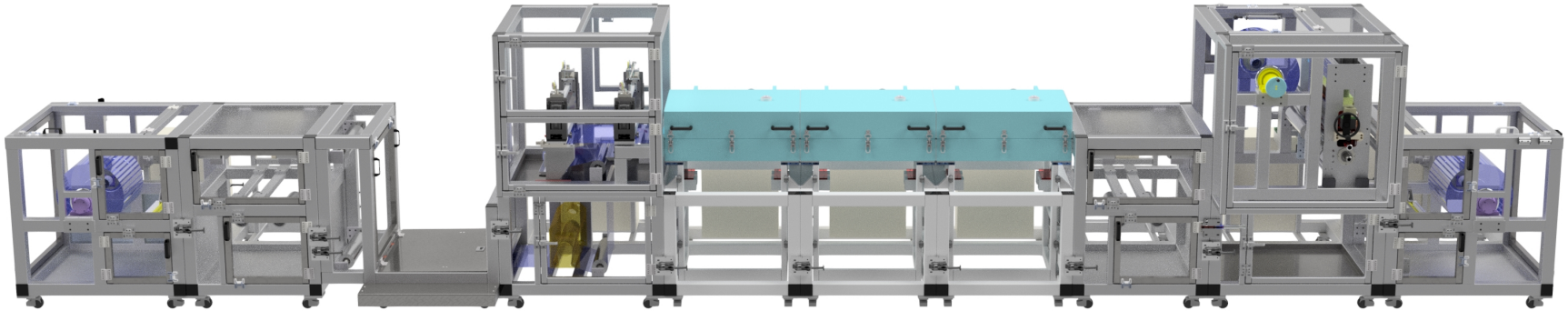
R2R pilot

Basecoater Pilot R2R

The Click&Coat™

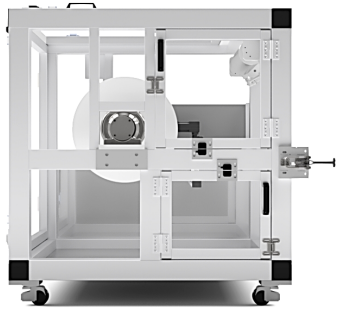


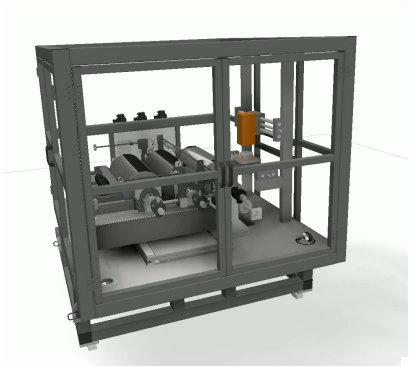
The Click&Coat™

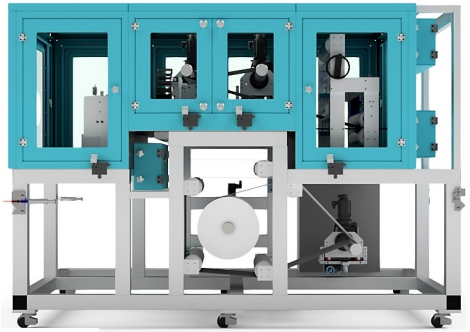


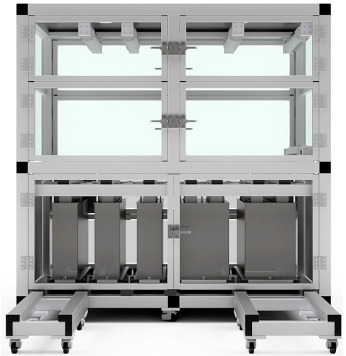
The Click&Coat™

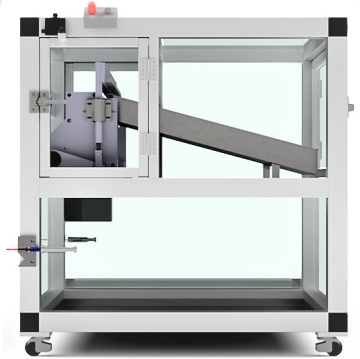
The Click&Coat™ single modules



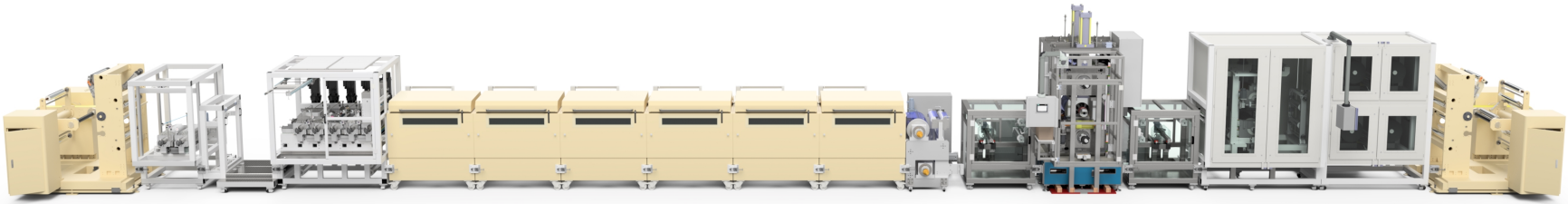








The Click&Coat™ in production scale in the R&D centre



The Click&Coat™ in production scale

The Click&Coat™ in production scale

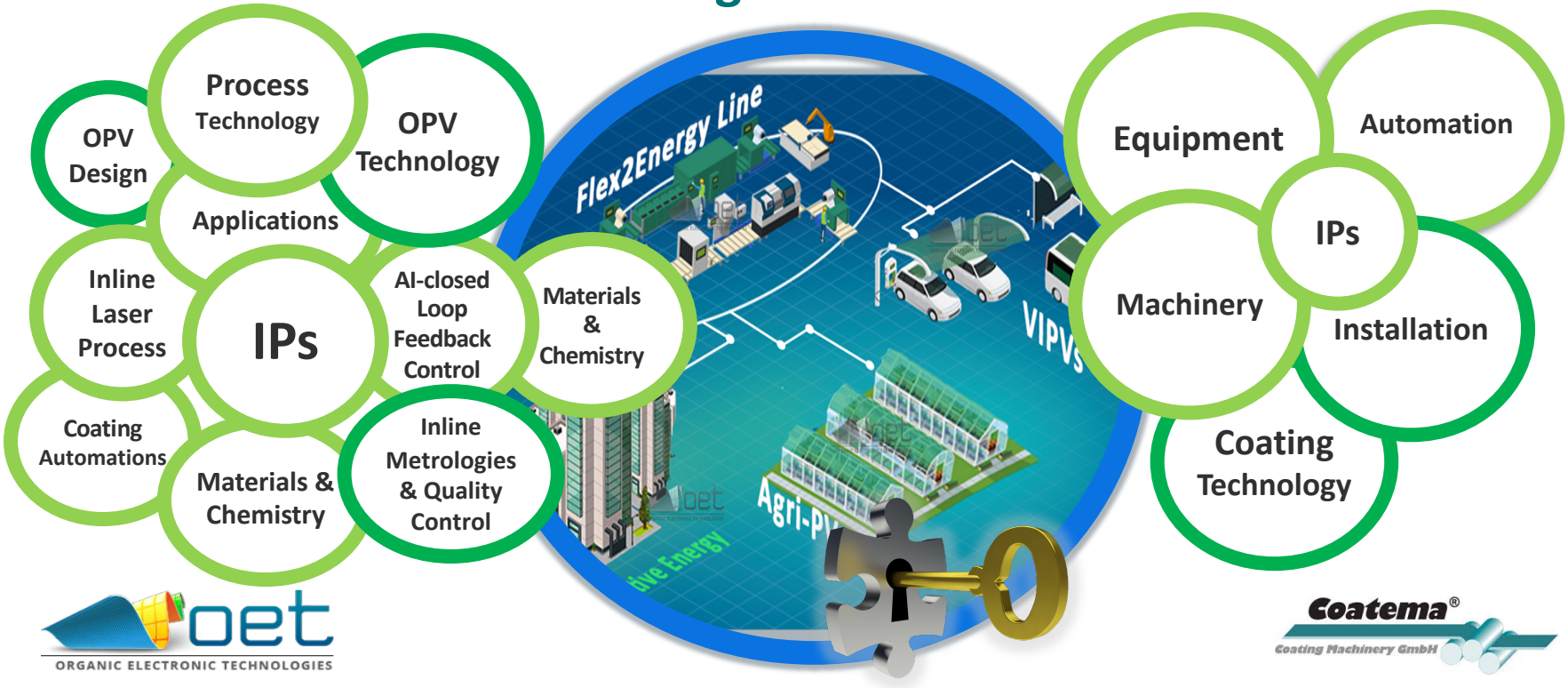
8.

Summary

Outlook

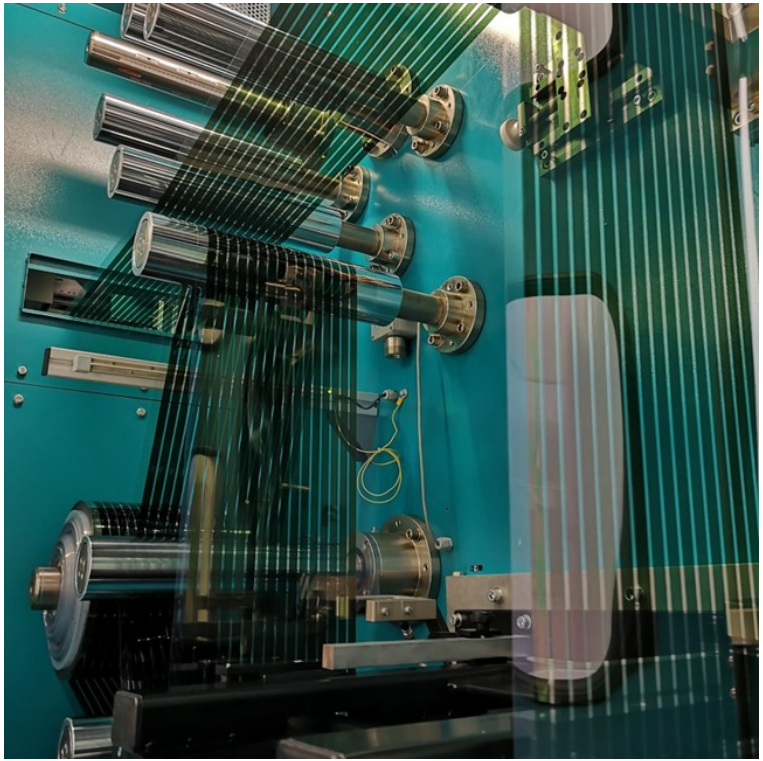
- ✓ Impact markets will be Agrivoltaics and BIPV
- ✓ New green deal of the European Comission
- ✓ Coatema has over 15 years experience in the market of 3rd Gen equipment
- ✓ OET has over 30 years experience in the development of Nanotech and Quantum technologies
- ✓ Together we offer the whole Lab2Fab upscale for your technologies
- ✓ Get the gigafab for OPV agrivoltaics today and get the full package including materials, product design, equipment and fab layout

OET – COATEMA: Towards Giga Fab for OPV



Mission

Open OPV market and deliver **highly efficient OPV products** integrated in infrastructures, agriculture and building elements with **high aesthetics**, aiming to **energy positive** and zero-emission buildings.



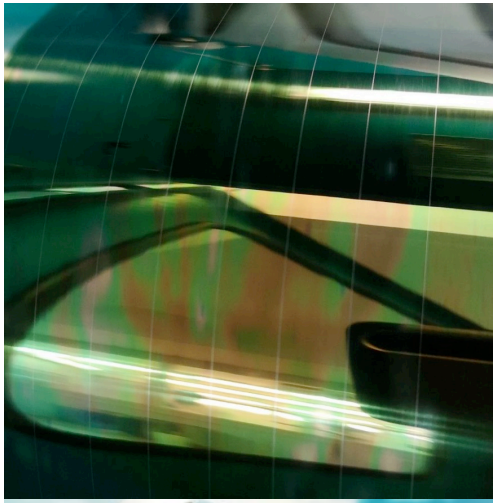
Vision

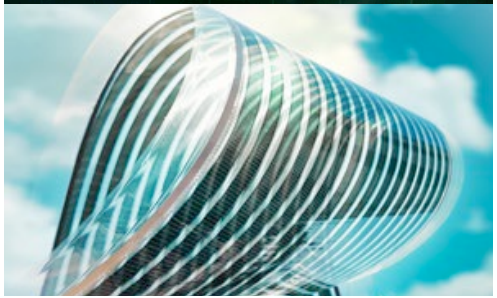
„Sustainable electricity from any surface and everywhere”

OPV Development at OET

OET facts and figures

- ✓ Founded in 2012
- ✓ Nanotechnology driven company
- ✓ 30 years experience in Thin Film Technologies
- ✓ 18 years in FPEs
- ✓ Expert in R2R Manufacturing of FPEs
- ✓ Patents and IPs in R2R Manufacturing, In-line Metrologies
- ✓ In-line Laser Processes, OPV Applications
- ✓ 30 people working on R&D topics





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Do not hesitate to contact us!

Anything missing?

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