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# WELCOME TO THE 3<sup>RD</sup> FRAUNHOFER GREEN DEAL WEBINAR

09 March 2021 | 9:00 – 10:00 a.m.

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## Fraunhofer Green Deal Series

**"The Photovoltaics Renaissance – New opportunities for a key enabler of the clean energy transition"**

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# AGENDA

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- [Slide 3](#) **Welcome and introduction by Prof. Andreas Bett**  
Director Fraunhofer Institute for Solar Energy Systems ISE
- [Slide 15](#) **Expert presentation I “PV production: New opportunities for Europe”**  
Dr. Ralf Preu, Division Director Fraunhofer Institute for Solar Energy Systems ISE
- [Slide 30](#) **Expert presentation II “Integrated Photovoltaics: Activating Surfaces for Green Electricity Generation”**  
Dr. Harry Wirth, Division Director Fraunhofer Institute for Solar Energy Systems ISE

# Welcome and introduction

**by Prof. Andreas Bett**

Director of Fraunhofer-Institute for Solar Energy Systems ISE



# Fraunhofer Institute for Solar Energy Systems ISE

## Research for the Energy Transformation



### Directors

Prof. Dr. Hans-Martin Henning

Prof. Dr. Andreas Bett

### Staff

ca. 1250

### Budget 2020 (preliminary)

Operation €91.2 million

Investment €13.6 million

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Total €104.8 million



# Fraunhofer ISE

## Areas of Concentration

### ENERGY TECHNOLOGIES AND SYSTEMS

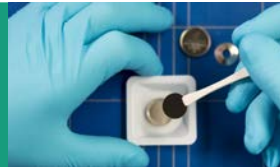
Energy Efficient Buildings



Solar Thermal Power Plants and Industrial Processes



Hydrogen Technologies and Electrical Energy Storage

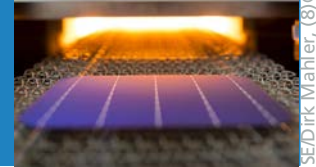


Power Electronics, Grids and Smart Systems

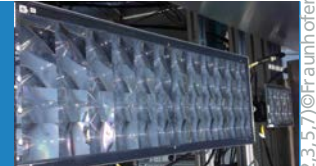


### PHOTOVOLTAICS

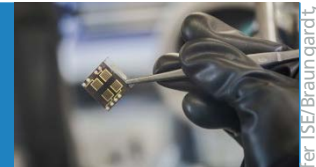
Silicon Photovoltaics



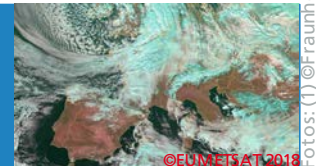
III-V and Concentrator Photovoltaics



Perovskite and Organic Photovoltaics



Photovoltaic Modules and Power Plants



# Photovoltaics: THE Pillar for the Carbon-free Energy Supply!

## Growing Markets Need Sustainable Industrial Production

- In 2018 Fraunhofer ISE starts the initiative:

### 10GWGreenFAB

Manufacturing of PV in Europe to maintain the technological sovereignty and independency.

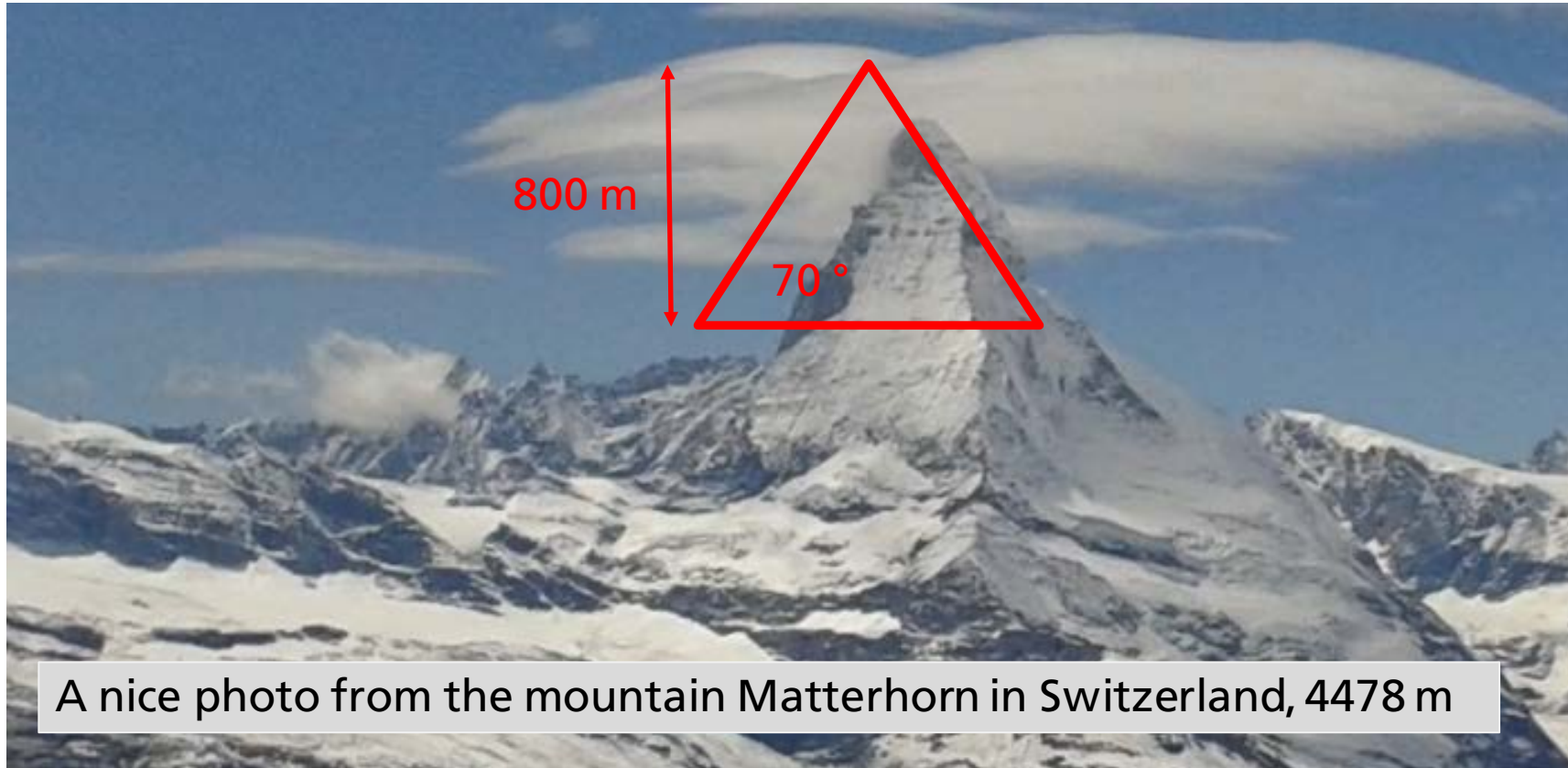


see: <https://www.ise.fraunhofer.de/en/renewable-energy-data.html>

# Motivation for Circle Economy



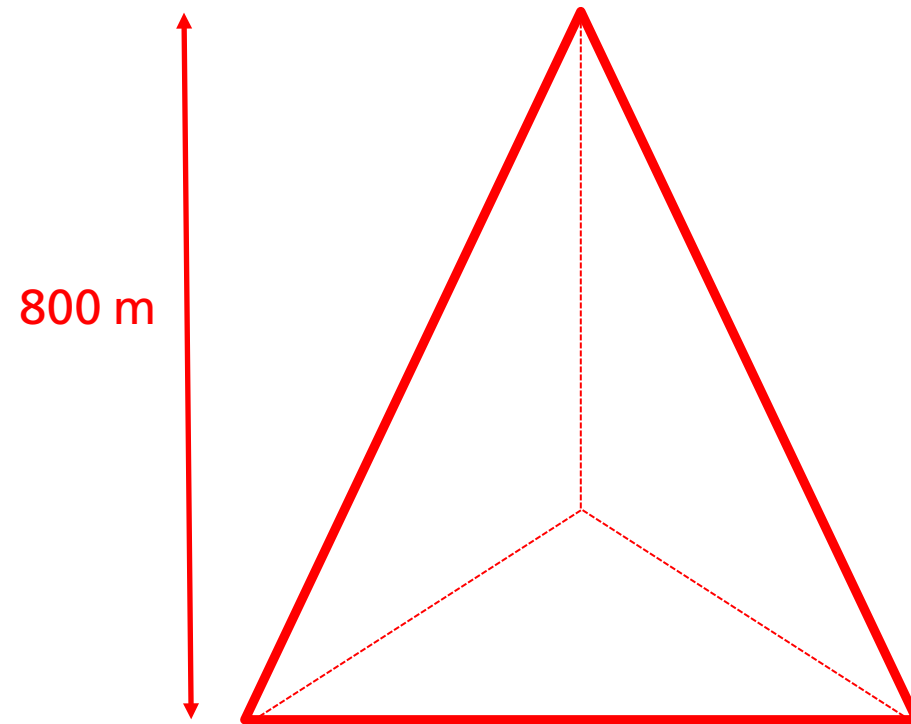
# Motivation for Circle Economy





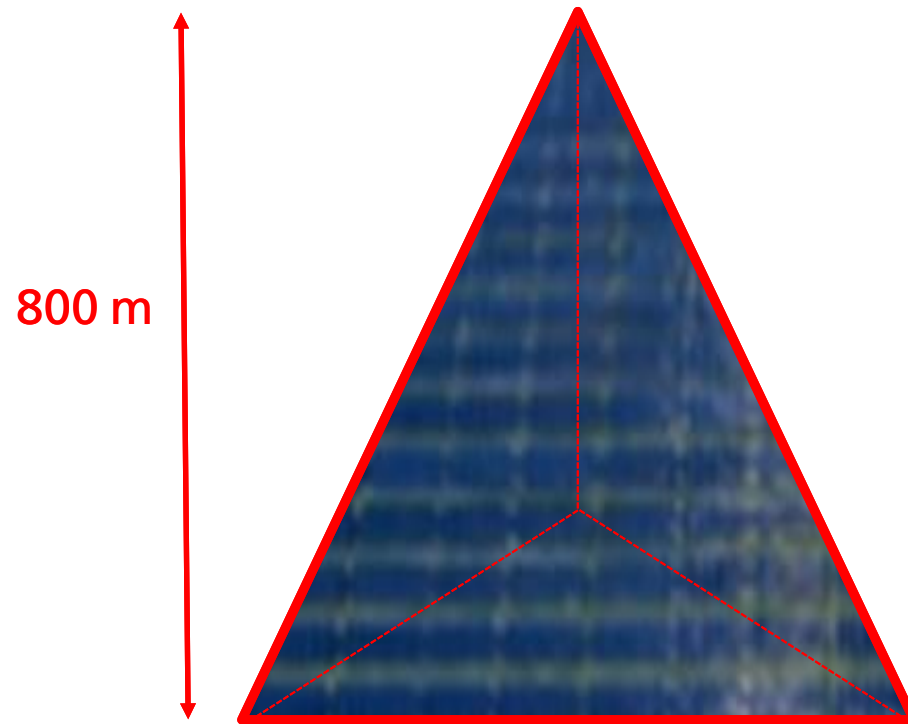
# Motivation for Circle Economy

## Recycling is Needed



# Motivation for Circle Economy

## Recycling is Needed



Module:  
300 Wp,  $1.67 \times 1.0 \times 0.033 \text{ m}^3$ , 18 kg

→ only ~200 GW, today 750 GW  
future: 70.000 GW!

# Photovoltaics: THE Pillar for our Carbon-free Energy Supply

## Growing Markets Need Sustainable Industrial Production

- 10 GW<sub>p</sub> fully integrated production in Europe is competitive
  - **Cost advantages >10 %** due to reduced logistic costs
  - Production with **less CO<sub>2</sub> emission**
- Alignment within Europe
  - ESMC (European Solar Manufacturing Council)
  - Solar Europe Now
  - Solar Power Europe + EIT Solar Energy → European Solar Initiative
  - ETIP-PV

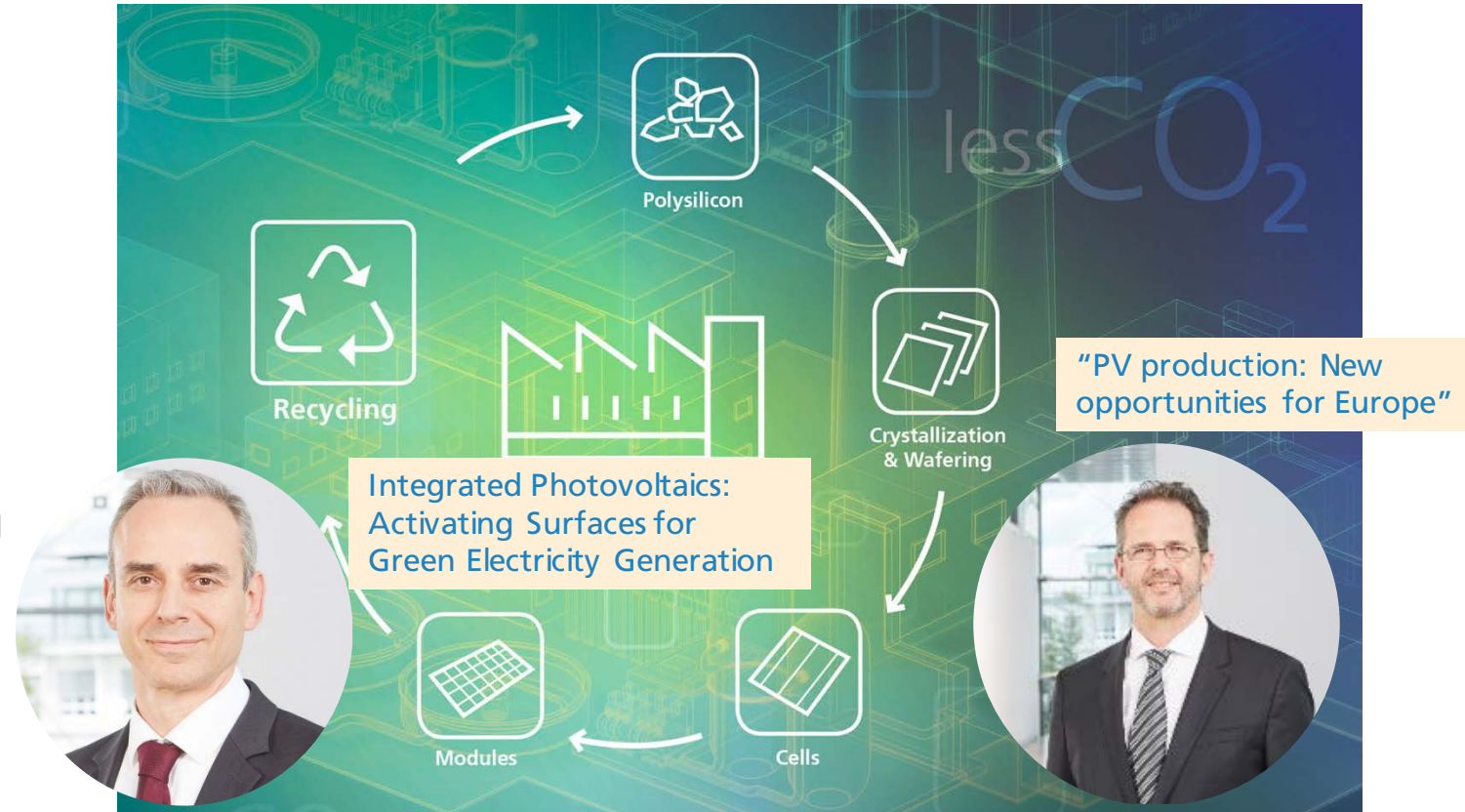


see: <https://www.ise.fraunhofer.de/en/renewable-energy-data.html>

# Photovoltaics: THE Pillar for our Carbon-free Energy Supply

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# Contact



Fraunhofer Institute for Solar Energy Systems ISE

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# Setting the scene

by **Michael Bloss**

Patron of the webinar

Member of the European Parliament



# Expert presentation I “PV production: New opportunities for Europe”

**By Dr. Ralf Preu**

Director Photovoltaics - Production Technology  
Fraunhofer Institute for Solar Energy Systems ISE



# Agenda

- PV-market: History and Outlook
- Competitiveness of European PV Production
  - Costs
  - Sustainability
  - Innovative PV-Technology
  - New Production in Europe
- Summary



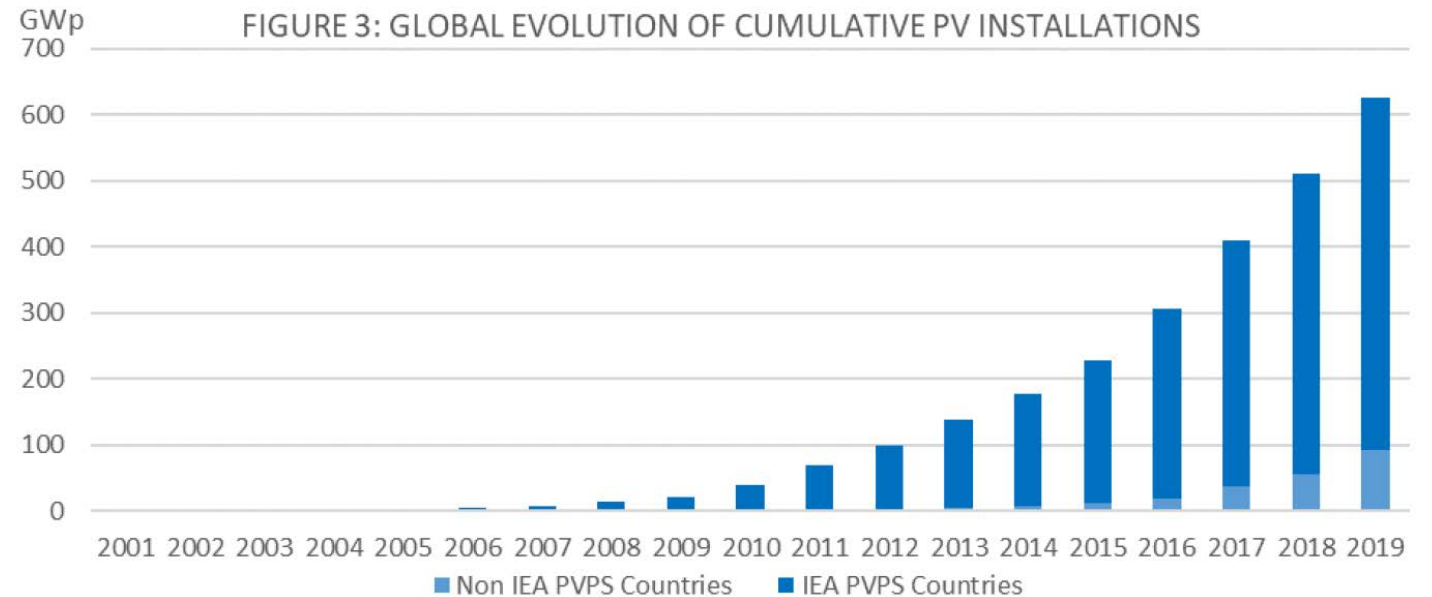
Combined PV and Wind System Tenerife, Spain



# PV-market: History and Outlook

## Historical development of global PV installation

- Photovoltaics has experienced steady growth worldwide
- IEA: cumulative installed PV capacity by 2019: 629 GW<sub>p</sub>



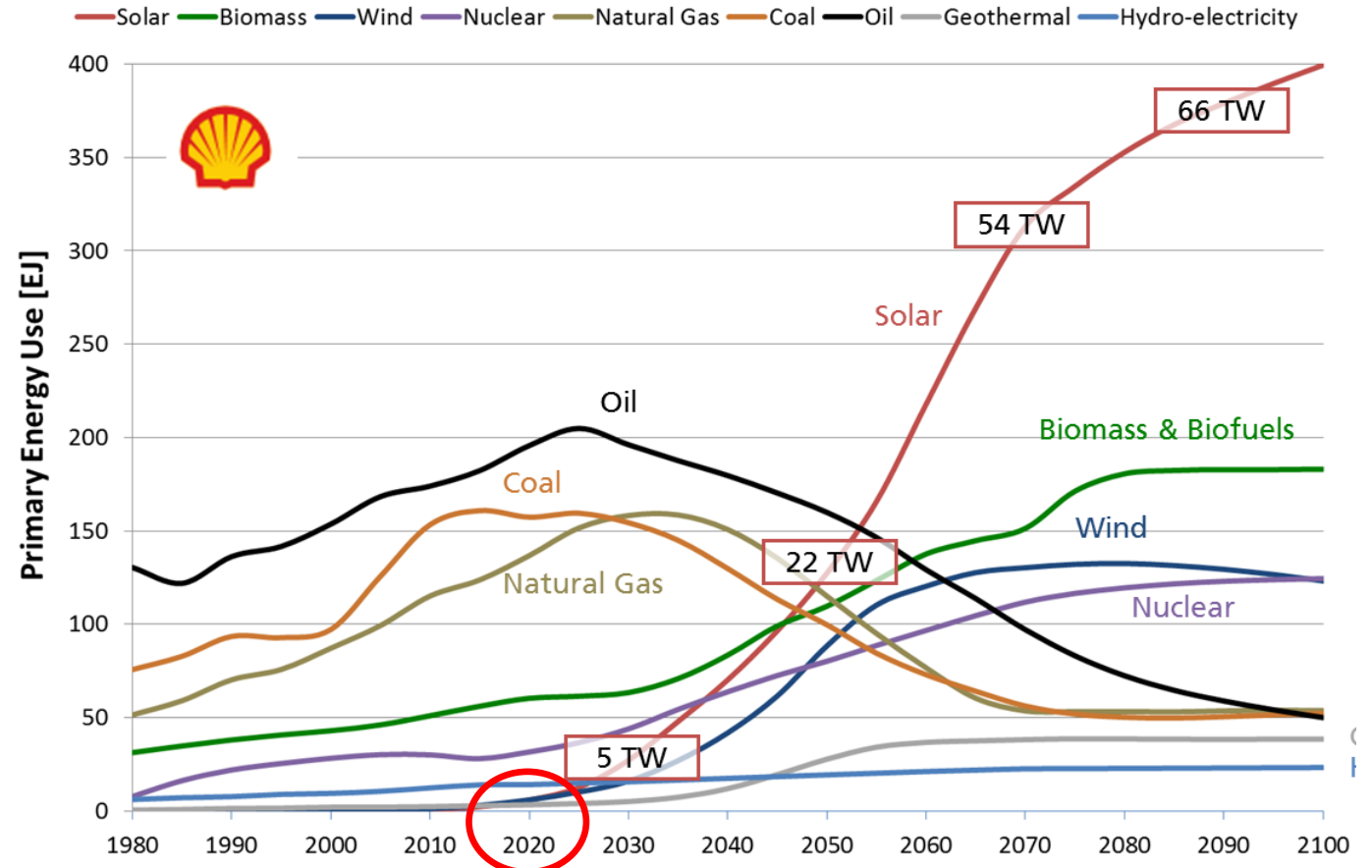
### Global Evolution of Cumulative PV Installations

Source: Report IEA-PVPS T1-37: 2020

# PV-market: History and Outlook

## Future development of energy sources– Shell Sky Scenario

- PV - steady growth
- IEA: cumulative installed PV capacity by 2019: 629 GW<sub>p</sub>
- Shell: PV - the most important energy source by mid-century



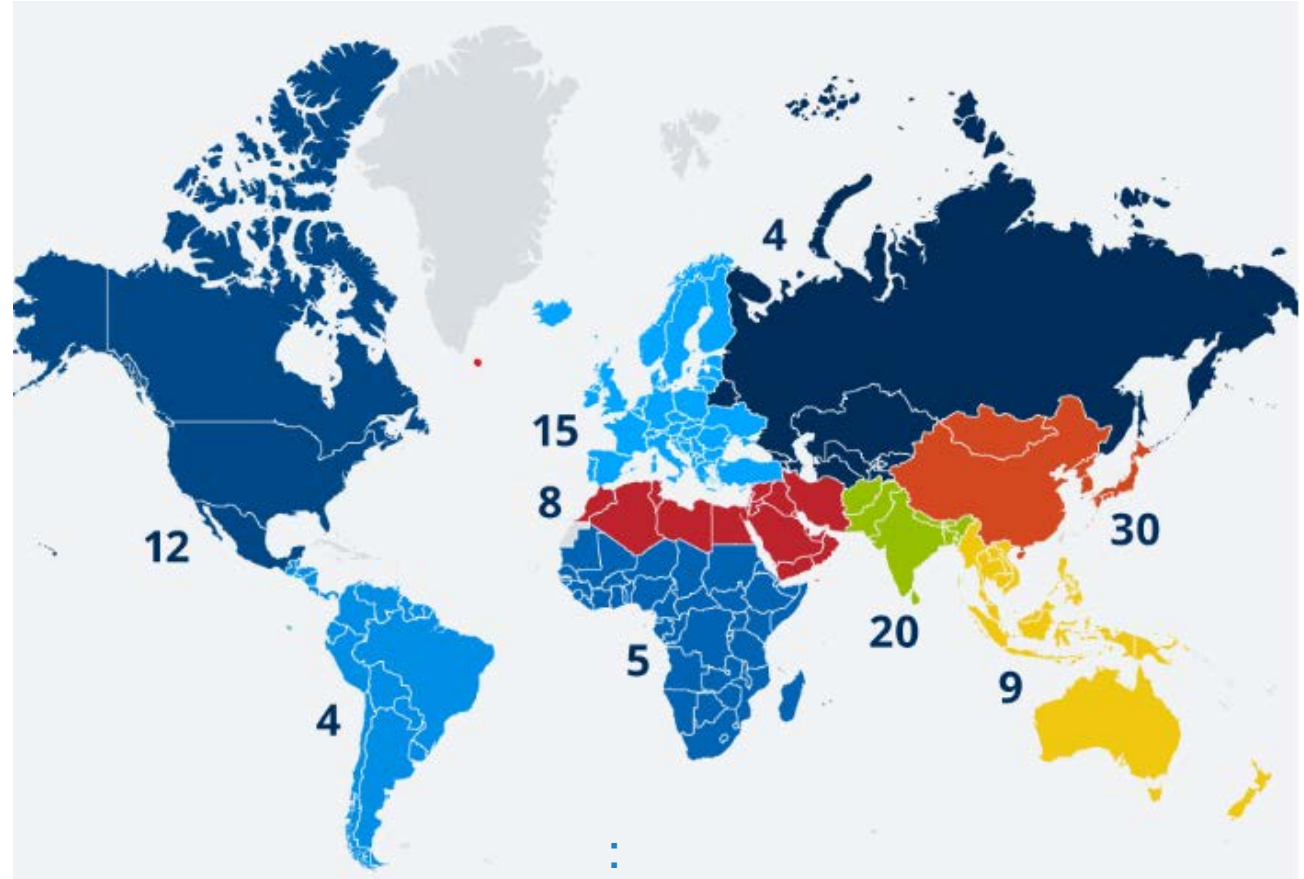
Shell Sky scenario for this century's primary energy supply

Source: <https://www.carbonbrief.org/in-depth-is-shells-new-climate-scenario-as-radical-as-it-says>

# PV-market: History and Outlook

## LUT/Energy Watch Group Scenario – Gigafab demand

- PV - steady growth
  - IEA: cumulative installed PV capacity by 2019: 629 GW<sub>p</sub>
  - Shell: PV - the most important energy source by mid-century
  - LUT/Energy Watch Group: cost-efficient 1,5 K scenario
    - 8,800 GW installed in 2035 (ca. 40,000 km<sup>2</sup>, size of NL)
    - 15 Gigafactories needed (60 GW PV each)



Number of 60 GW-PV-factories needed for 1.5 K target, cost-efficiently.

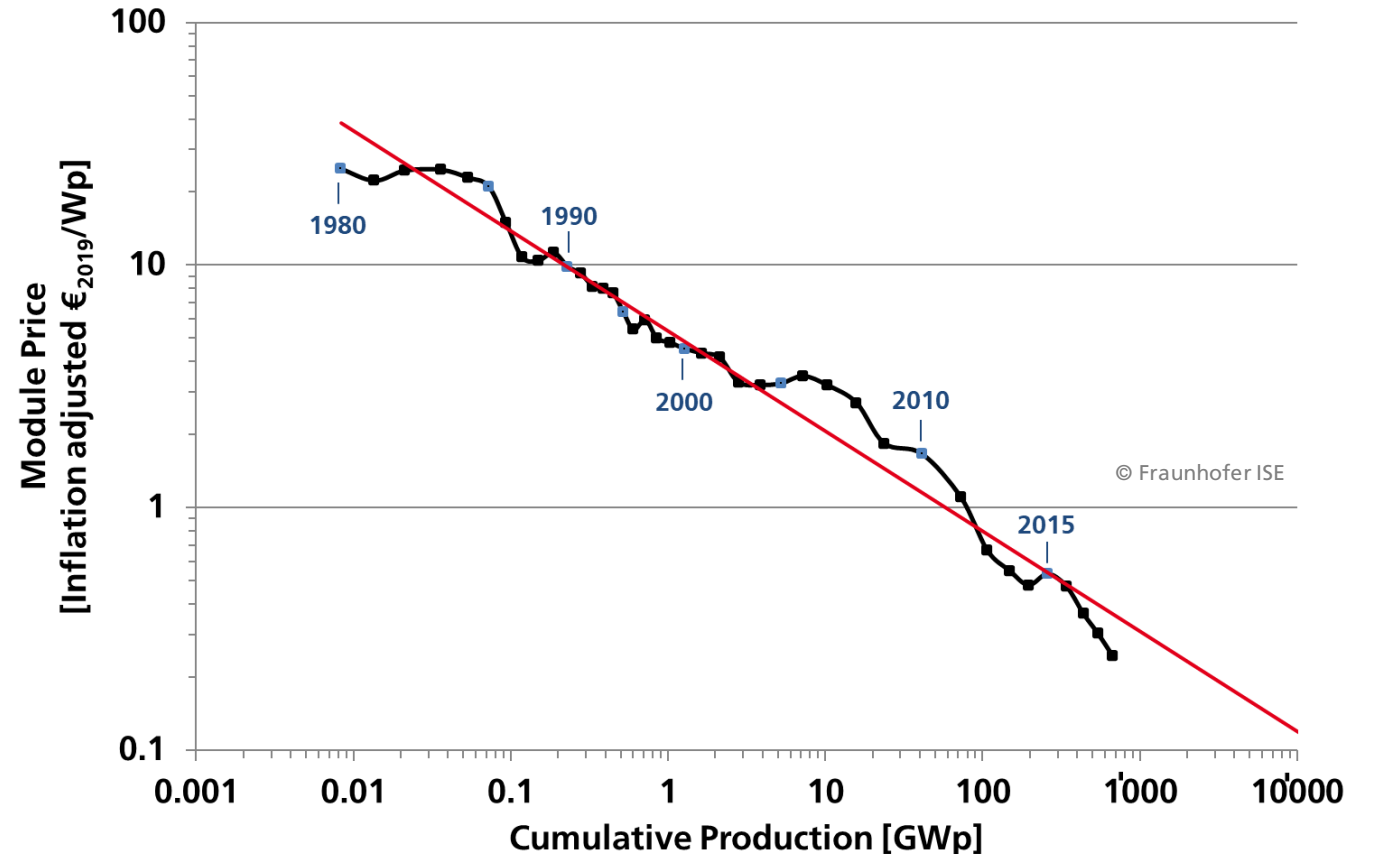
Source: Lappeenranta University of Technology/Energy Watch Group in <https://www.dw.com/de/globale-energiewende-braucht-100-solarmodul-fabriken-sofort/a-56145363>

# PV-market: History and Outlook

## Price experience curve: all commercially available PV technologies

### ■ Learning rate:

- the price has fallen by 25%  
Each doubling of cumulative production
- 85% price decrease since 2011
- 2020: approx. 22 €ct/Wp



Global Evolution of Module Price vs Cumulative Production

Graph: PSE/Fraunhofer ISE 2020



# PV-market: History and Outlook

## Price experience curve: all commercially available PV technologies

### ■ Learning rate:

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- 85% price decrease since 2011
- 2020: approx. 22 €ct/Wp

### ■ Current average Power Purchase Agreement price in Spain<sup>1</sup>:

- 2.45 €ct/kWh

# PV-market: History and Outlook

## Installed PV capacity in Europe 2000-2020

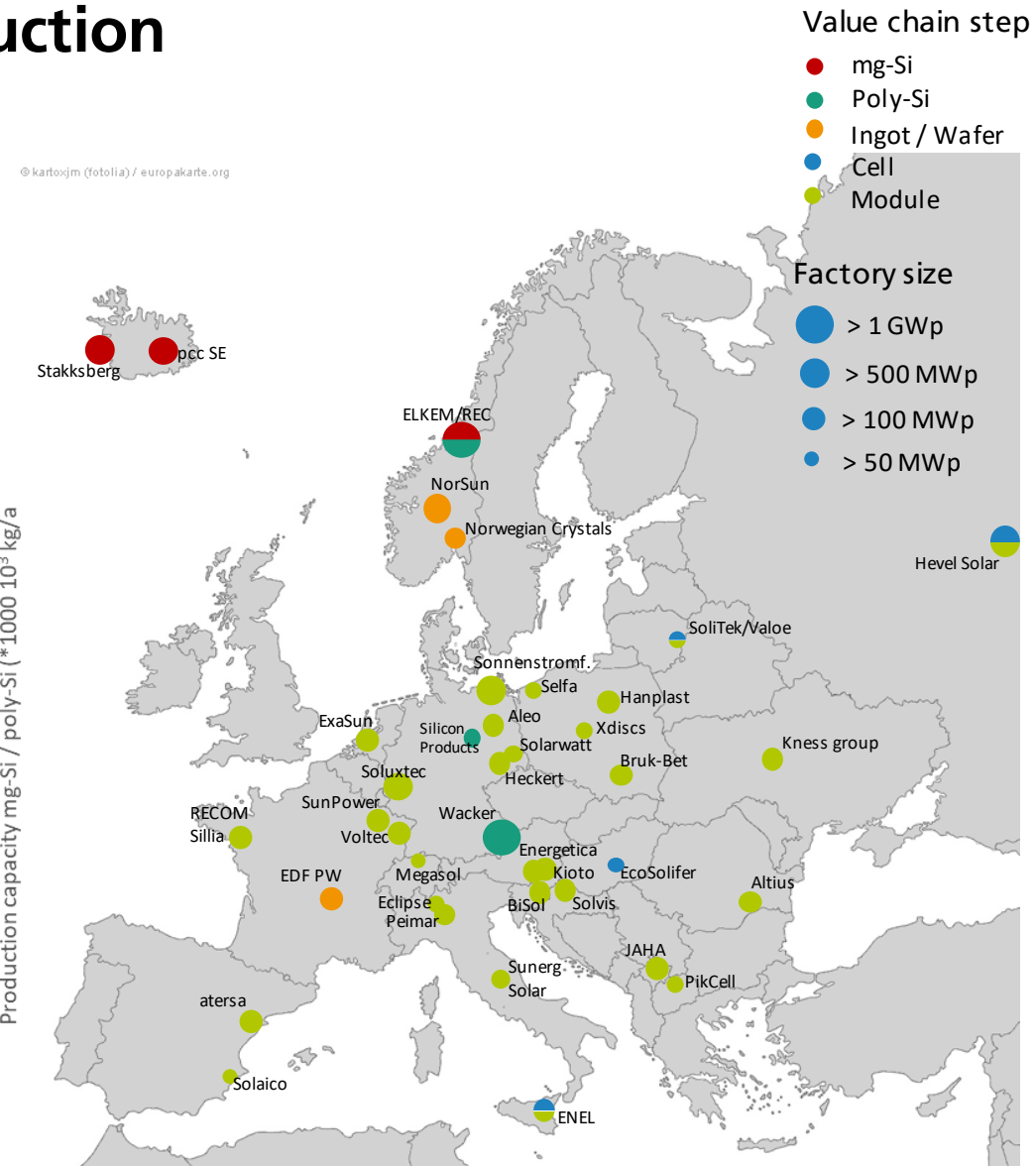
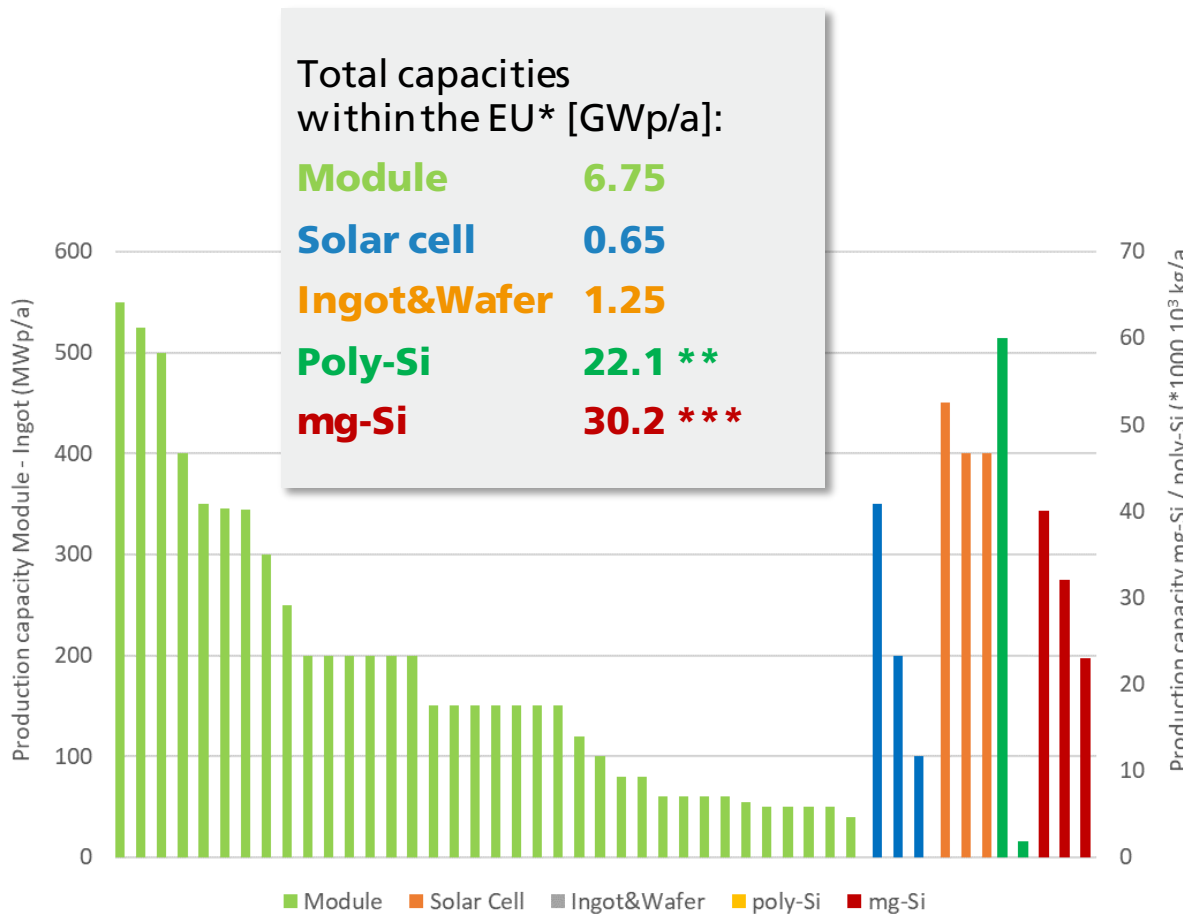
- Strong national market fluctuations
- European PV industry
  - until 2011: strong growth
  - 2012-2017:
    - collapse of EU-PV producer
    - enormous build up of PV in China with EU equipment and technology
  - since 2018: a few innovative EU benchmark equipment maker

European PV-market 2000-2020.

Source: Solar Power Europe

# Competitiveness of European PV Production

## Status of PV production in Europe

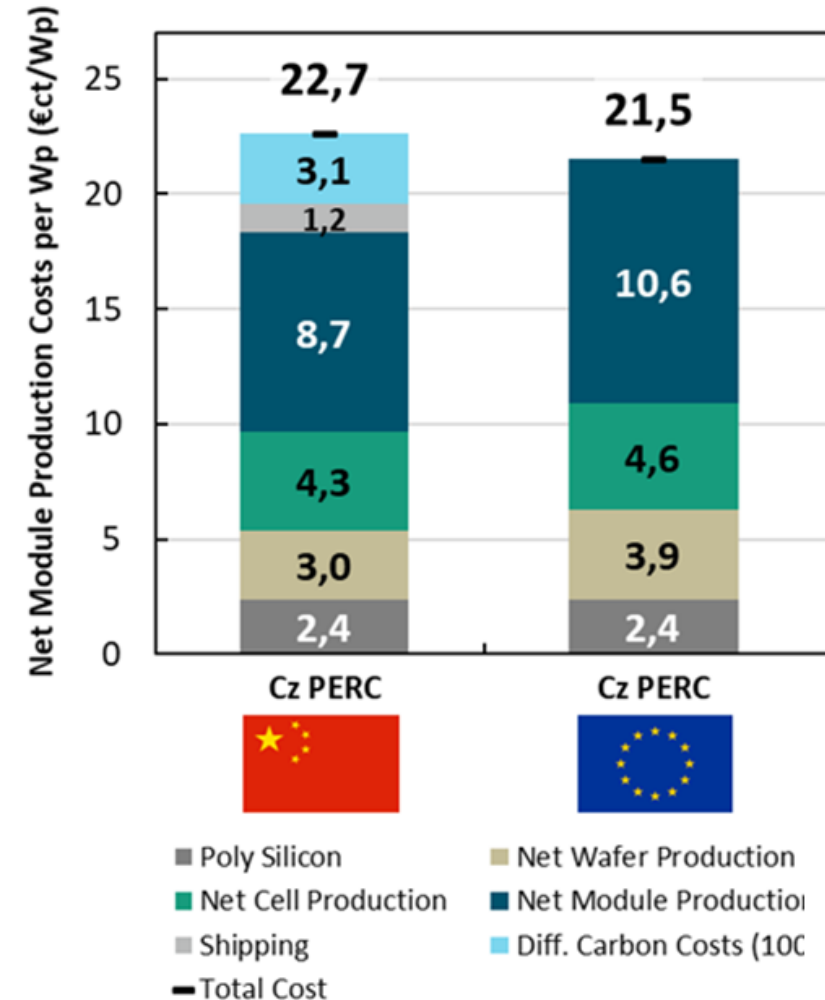


# Competitiveness of European PV Production

## Scenario analysis: cost

- VDMA/ISE Study 2019: Scenario Analysis for PERC Module Manufacturing Costs
- Bottom-up calculation with industry data
- Competitive PV production in Germany – Requirements
  - Strong EU market
  - Production scale (multi-GW)
  - EU-value chain
  - Fair carbon emission trading / compensation system

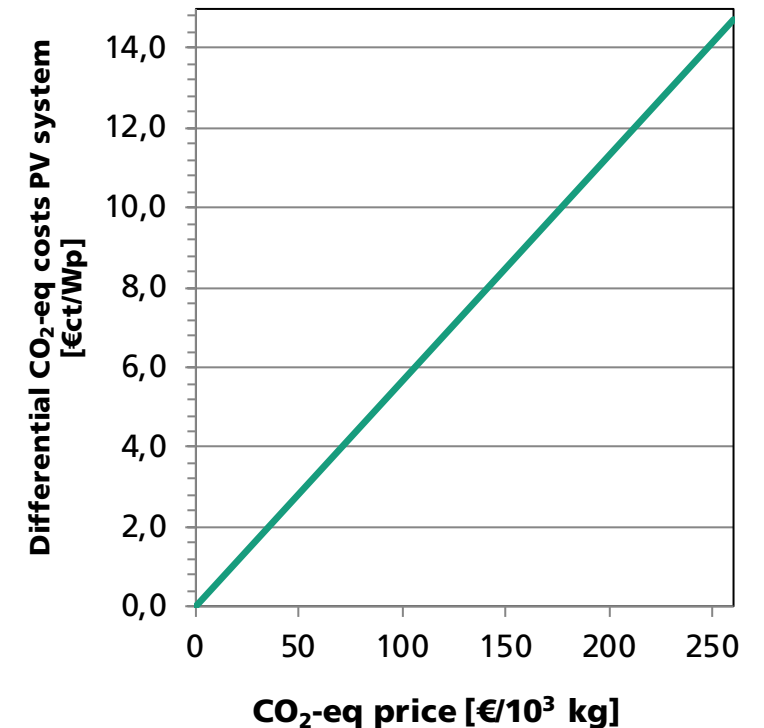
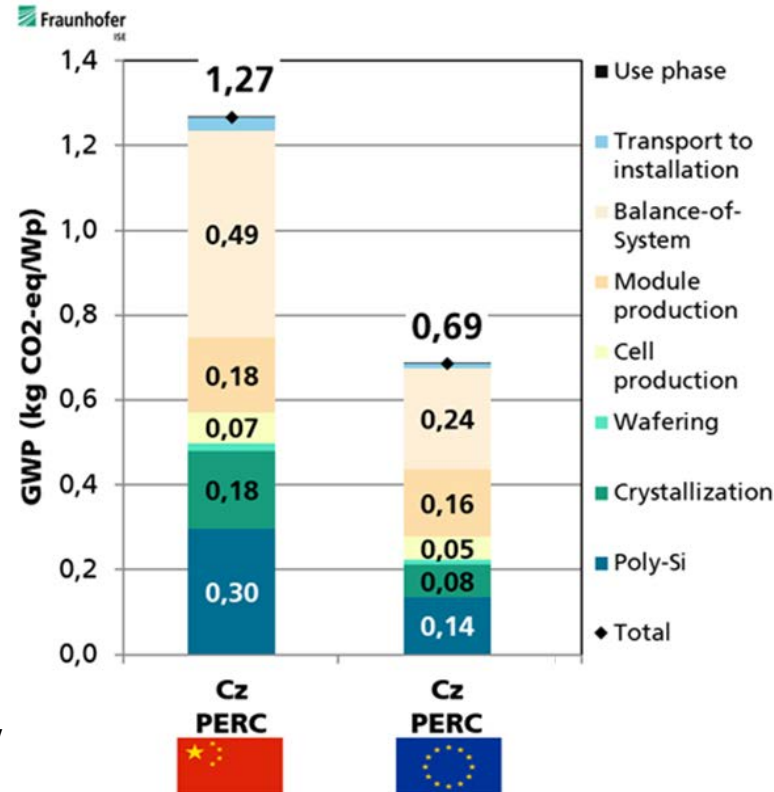
PERC: Passivated Emitter and Rear Cell, PV technology predominant today



# Competitiveness of European PV Production

## Scenario analysis: sustainability

- VDMA/ISE Study 2019: Scenario Analysis for PERC Module Manufacturing Costs
- Bottom-up calculation with industry data
- Competitive PV production in Germany – Requirements
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PERC: Passivated Emitter and Rear Cell, PV technology predominant today

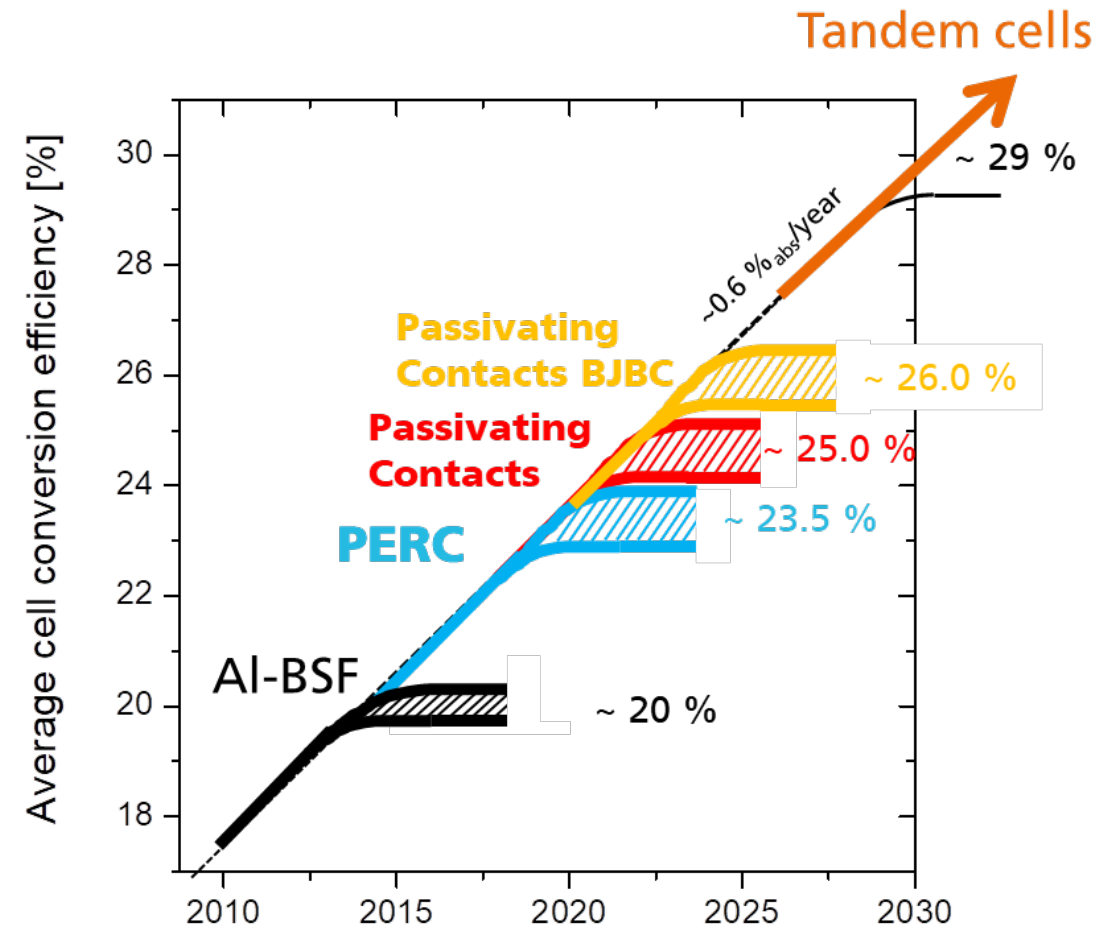
\*Source: Friedrich et al. (2020) – GWP and EPBT Analysis of PV Electricity by PERC Solar Modules, Journal of Photovoltaics, submitted.



# Competitiveness of European PV Production

## Innovation: Record Cell efficiencies and production technology from Europe

- Passivated Emitter and Rear Cell covers more than 80% of world market in 2021
- Recent Laboratory Records
  - Si-TOPCon: 26.0 % (Europe)**
  - BJ-HJT: 26.7% (Japan)
  - Pero/Si-Tandem: 29.5% (Europe)**
  - III-V/Si-Tandem: 34.5% (Europe)**
- Production technology
  - fast
  - reduction of scarce materials
  - digital



# Competitiveness of European PV Production

## New Initiatives

### HJT

		capacity / GW
■ MeyerBurger	Cell+Module	0.4/1.4 GW
■ EnCore (Hevel)	Ingot&Wafer+Cell	1 GW
■ REC	Cell+Module	2 GW

### PERC/TOPCon

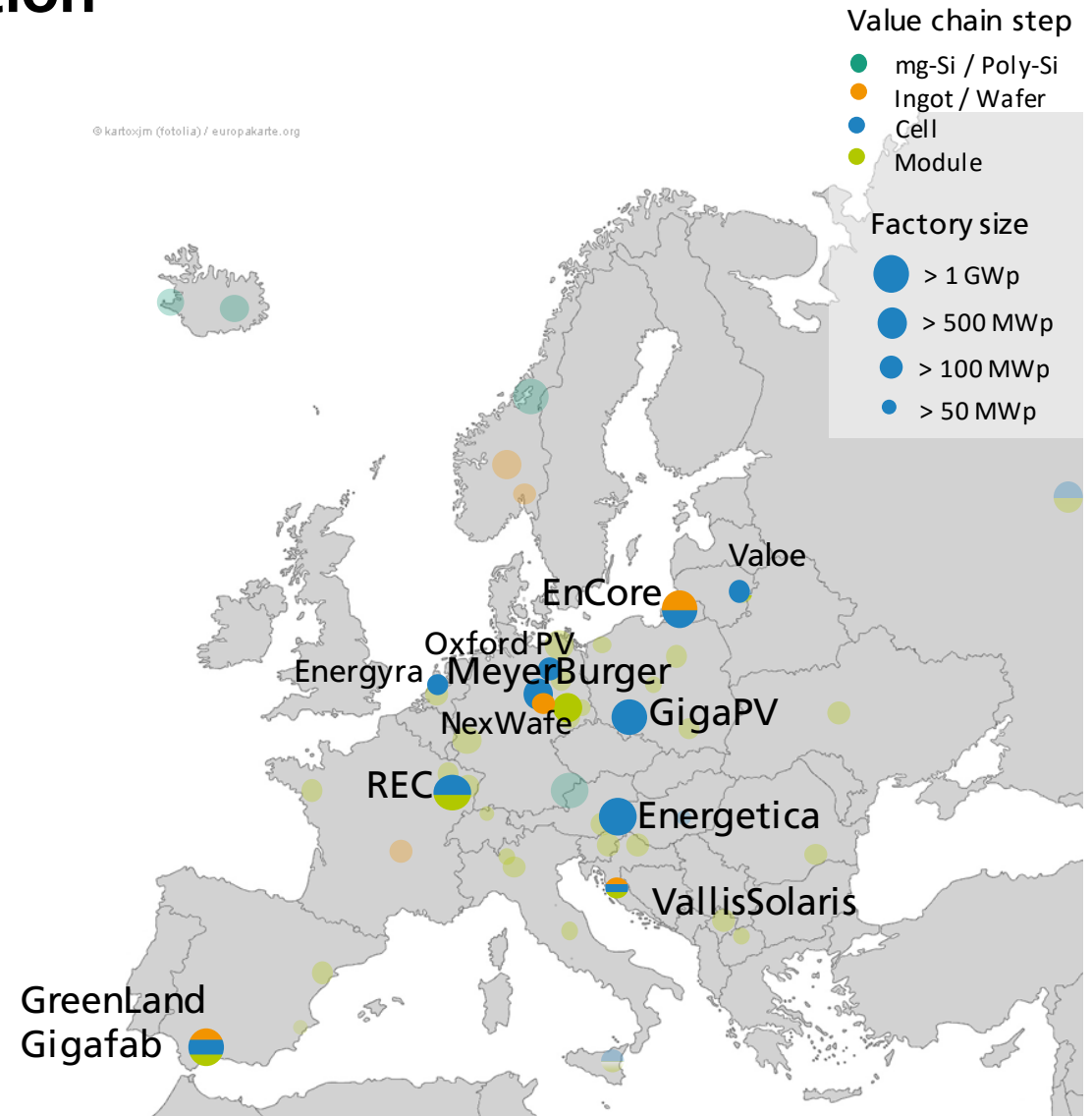
■ GreenLand Gigafab	Ingot – Module	1 GW
■ VallisSolaris	Ingot – Module	1 GW
■ Energetica	Cell+Module	1 GW

### Tandem

■ Oxford PV	Cell	250 MW
■ Giga PV	Cell	1 GW

### IBC

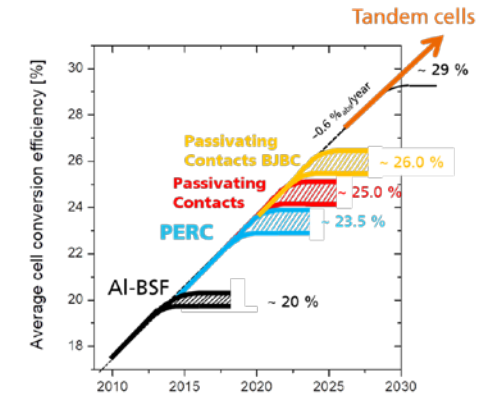
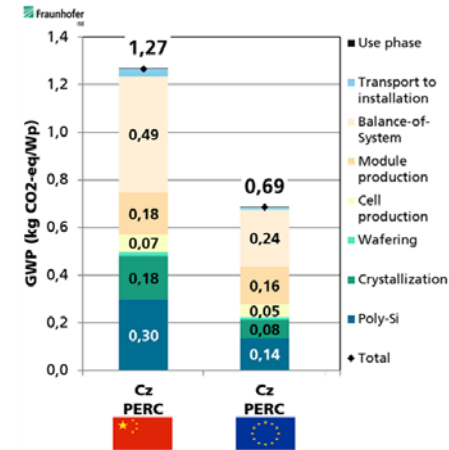
■ Valoe/Solitek	Cell+Module	60 MW
■ Energyra	Module	100 MW



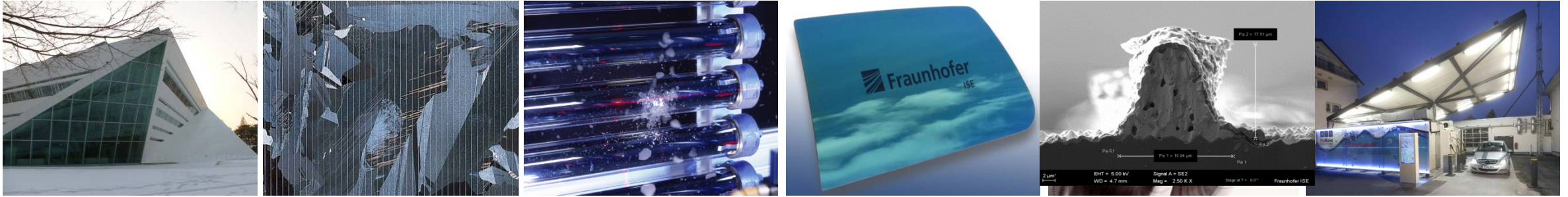
# Summary

## PV production: New opportunities for Europe

- We must
  - install up to 8,800 GW of PV modules in EU
  - realize short transport and reliable supply chain
  - use the sustainable European energy mix
- We can
  - use world leading next gen technology from European R&D
  - build big and sustainable PV Fabs



# Thank you for your Attention!



Fraunhofer Institute for Solar Energy Systems ISE

Dr. Ralf Preu

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# Expert presentation II

## “Integrated Photovoltaics: Activating Surfaces for Green Electricity Generation”

**By Dr. Harry Wirth**

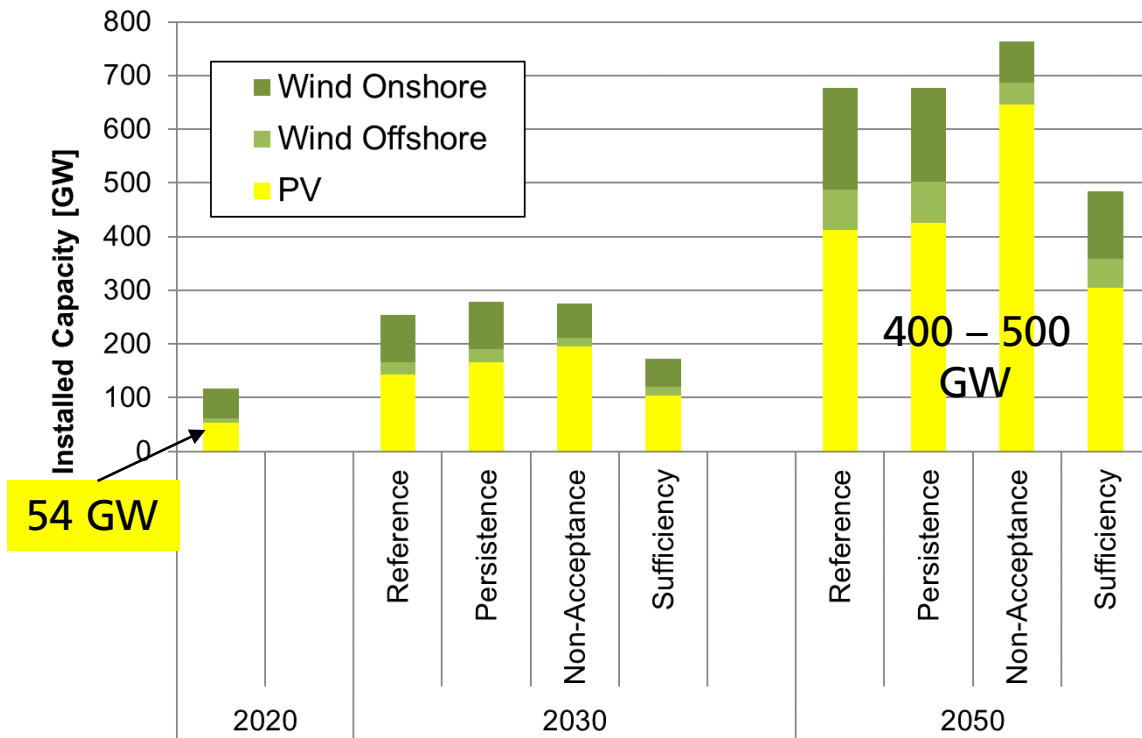
Division Director Fraunhofer Institute for Solar Energy  
Systems ISE





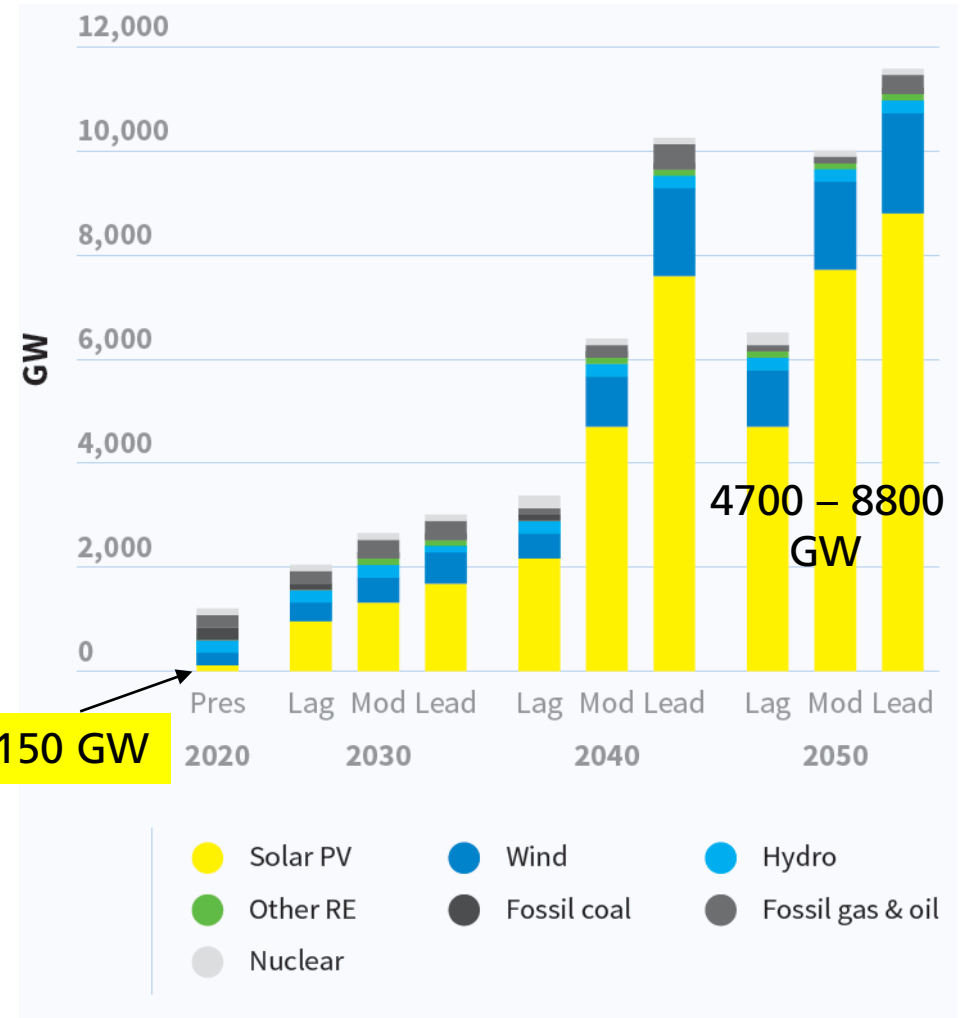
# PV Demand for Energy Transition Volumes

## ■ PV capacity demand in Europe on sharp rise



PV scenarios Germany

Wege zu einem klimaneutralen Energiesystem, Fraunhofer ISE, 2020



PV scenarios Europe

SolarPower Europe. © SOLARPOWER EUROPE 2019

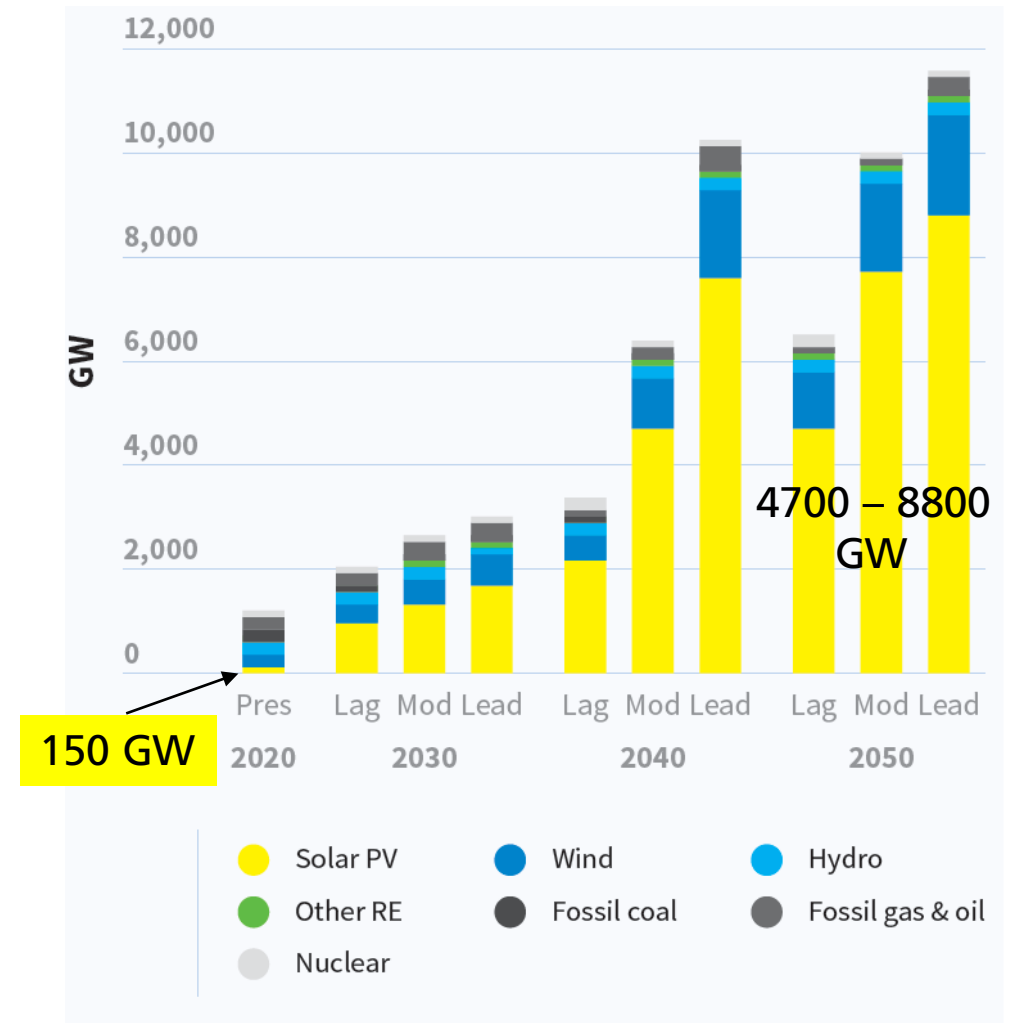
# PV Demand for Energy Transition

## Land use

- PV capacity demand in Europe on sharp rise
- PV requires large areas, typical
  - power 0,7 MW/ha
  - annual yield 700 MWh/ha (location dependent)
- Efficiency roadmaps expect 50% rise until 2050



**Land use for PV electricity generation becomes challenging**



PV scenarios Europe SolarPower Europe. © SOLARPOWER EUROPE 2019

# What is "Integrated Photovoltaics"?



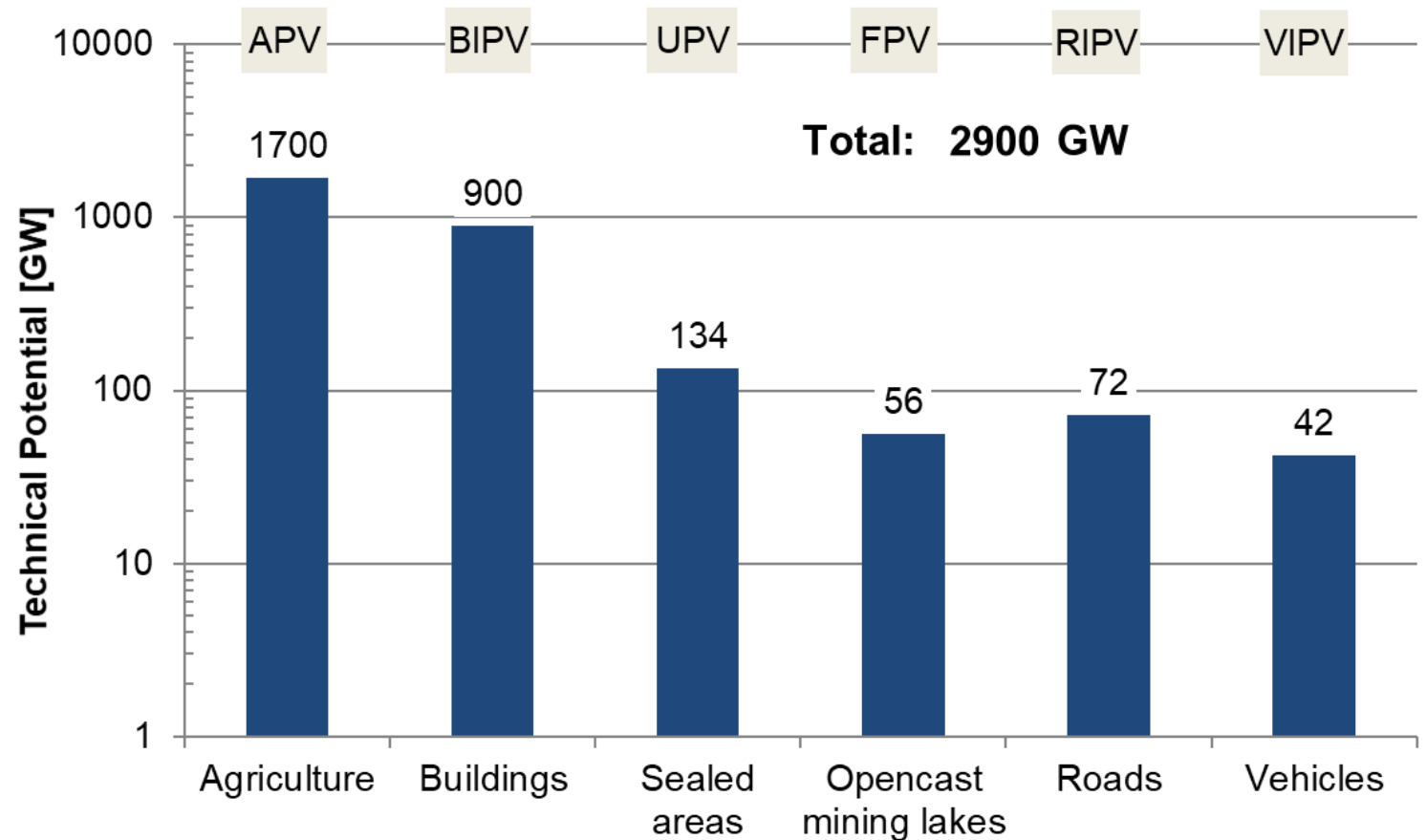
# Technical Potentials for Integrated PV (German Case Study)

## Rough Estimations

Theoretical Potential:  
restrictions from physics

**Technical Potential:**  
**fundamental technical  
restrictions**

Economical/Practical  
Potential:  
legal framework, cost,  
infrastructure, acceptance,  
ecology, competition





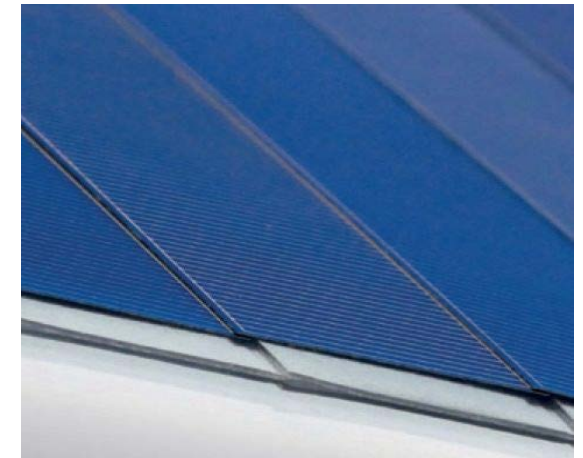
# Enabling Technologies for Integrated PV



MorphoColor® coating



Bifacial yield



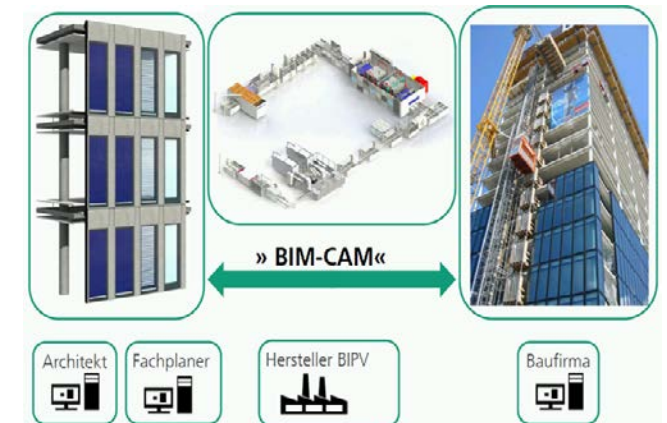
High Efficiency



Lightweight Design



Curved Design



Industry 4.0



# Integrated PV Agrivoltaics

## Additional benefits

- Strengthen resilience against climate change

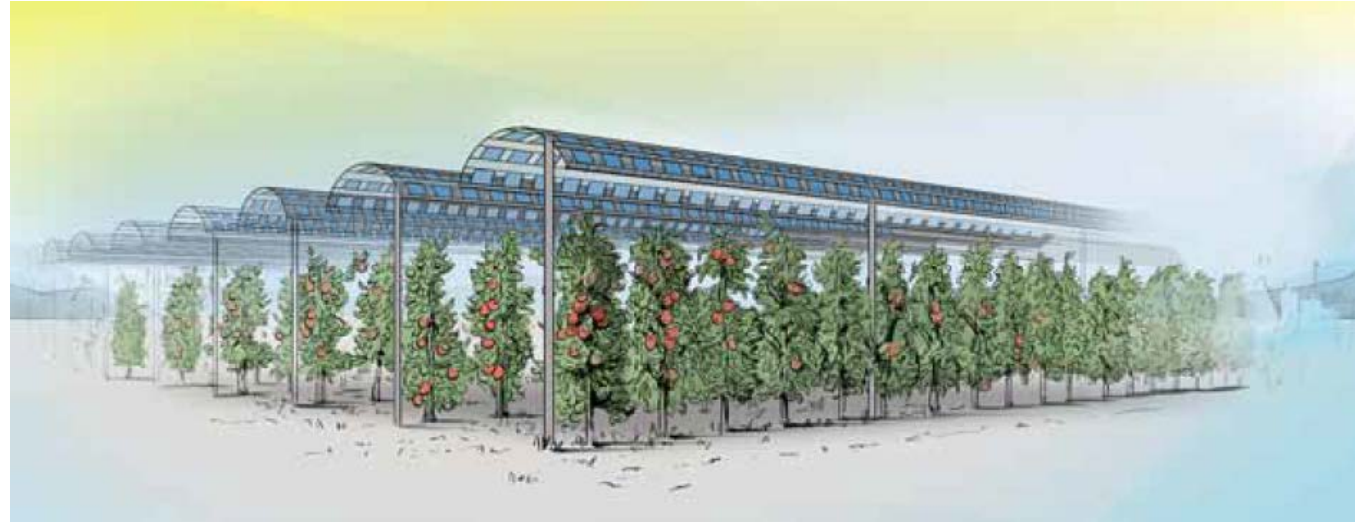


APV: Organic Farming (ISE/Baywa, Heggelbach, D)

# Integrated PV Agrivoltaics

## Additional benefits

- Strengthen resilience against climate change
- Protect sensitive crops
- Water management
- Double use of mounting structure
- Local customized mass production



APV: Orchard Visualisation)

# Integrated PV

## Building Integration

### Additional benefits

- Weather protection
- Double use of cover material
- Double use of mounting structure



BIPV: Laboratory façade (ISE)



# Integrated PV

## Building Integration

### Additional benefits

- Weather protection
- Double use of cover material
- Double use of mounting structure
- Local customized mass production

BIPV: invisible PV circuitry,  
glare-free coating (ISE)

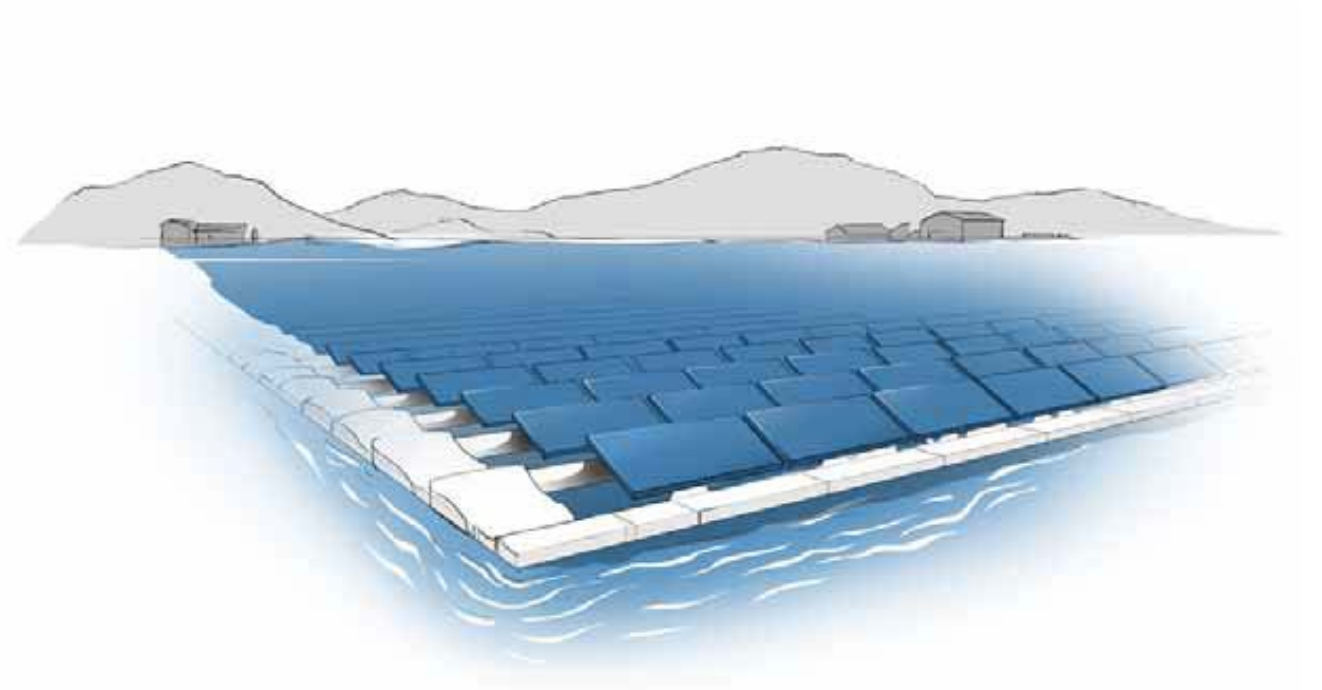


# Integrated PV

## Floating PV

### Additional benefits

- Increase electric yield
- Strengthen resilience of lake against climate change
- Reduce evaporation loss



FPV Visualization



# Integrated PV Vehicle Integration

## Additional benefits

- Reduce charging frequency
- Reduce carbon footprint

RIPV: Curved car roof with shingled solar cells and MorphoColor® coating (ISE)



# Integrated PV Vehicle Integration

## Additional benefits

- Reduce charging frequency
- Reduce carbon footprint
- Double use of cover material
- Double use of mounting structure
- Local customized mass production

VIPV: Utility car with light-weight modules (ISE)



# Integrated PV

## Road Integration

### Additional benefits

- Noise protection
- Double use of cover material
- Double use of mounting structure
- Weather protection
- Local customized mass production

RIPV: RIPV: Noise barrier, road roofing, bicycle roadway with PV





# Thank you very much for your attention!



## Integrated PV: Zero land consumption, multiple benefits, improved acceptance

Fraunhofer-Institut für Solare Energiesysteme ISE

Dr. Harry Wirth

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# THANK YOU FOR ATTENDING THIS FRAUNHOFER GREEN DEAL WEBINAR

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## Fraunhofer Green Deal Series

**"The Photovoltaics Renaissance – New opportunities for a key enabler of the clean energy transition"**