

**Prof. Dr. Andreas Bett**  
50th anniversary of the "Sun at the service of mankind"  
Paris, 12.12.2023

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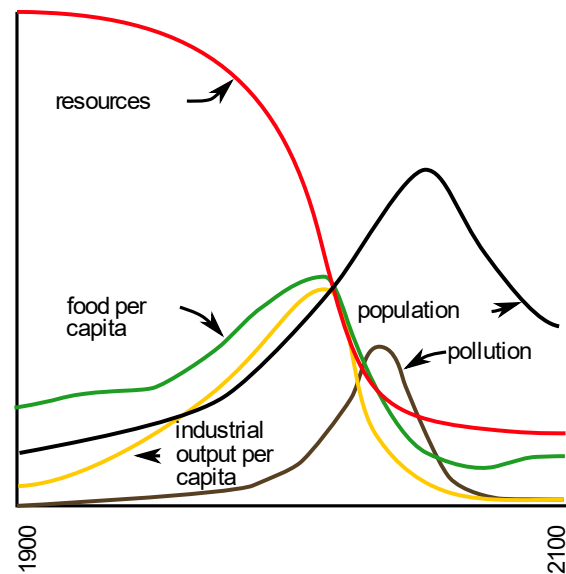
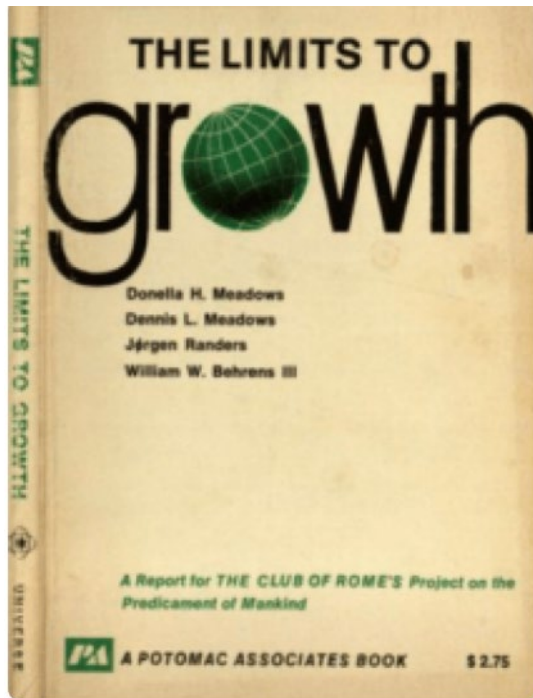
# Photovoltaics - from the Origins of Fraunhofer Institute for Solar Energy Systems to the Present Day

# Awareness on the Effects of Global Economic Activity

## Limits to Growth

### “Club of Rome”

The international organization was founded in 1968 and published its first major work in 1972 “The Limits to Growth”



Source: By YaguraStation - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=92084922>



Manhattan skyline enveloped in heavy smog, May 1973: Chester Higgins/NARA <https://www.motherjones.com/politics/2011/12/smog-photos-1970s-america/>

# The 70s and the Oil Crisis

## Oil crisis 1973 (and 1979):

The 1973 oil crisis was the result of the Yom Kippur War between Israel and the Arab states. The OPEC countries decided to reduce oil production and increase the price of oil. This led to considerable economic problems in many European countries, particularly in terms of rising inflation and unemployment.



# Founder of the Fraunhofer ISE

Prof. A. Goetzberger

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**In the pioneering days of microelectronics, he worked at the top addresses in US research.**

- 1958 to 1963 at William B. Shockley in Palo Alto, California and until
- 1968 at Bell Telephone Laboratories in Murray Hill NJ 1968 took over the management of Fraunhofer IEW, later IAF
- 1971 appointed Honorary Professor of the Faculty of Physics at the University of Freiburg



**I have always been attracted to problems that were considered unsolvable«**

**Prof. Dr. Adolf Goetzberger,  
Founder of Fraunhofer ISE**

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# Founder of the Fraunhofer ISE

Prof. A. Goetzberger

In the late 1970s, he decided to dedicate his life to solar energy

- 1977 succeeded with his IAF colleague in developing the fluorescent-activated display, project "Fluko"
- In 1978, the first Fraunhofer Prize was awarded for this project 1980 Founds a temporary working group for solar energy systems at the IAF
- **1981 Goetzberger** leaves the IAF with 20 employees, **founding of the Fraunhofer Institute for Solar Energy Systems** and headed it until 1993



It's better to be ahead of  
the times than behind«

Prof. Dr. Adolf Goetzberger,  
Founder of Fraunhofer ISE

# The First Site in Freiburg in the 80s: Oltmannsstraße

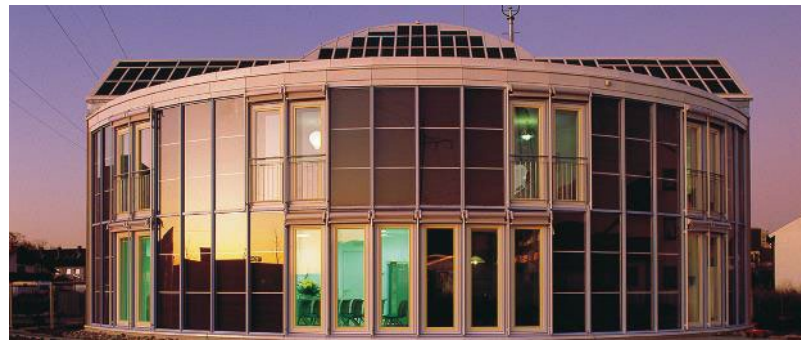


# Exemplary Research Topics at the Fraunhofer ISE in the 80s

The ISE Adopted a Systemic Approach from the Beginning



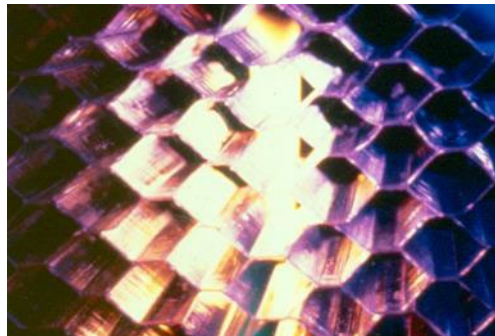
Fluorescence collector



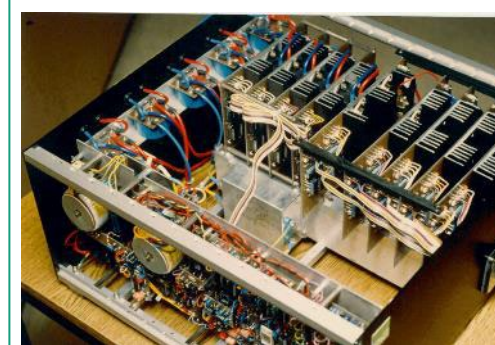
1992 Inauguration of the first energy self-sufficient solar house in Germany



1986: Europe's 1st PV powered hiking restaurant



Transparent thermal insulation



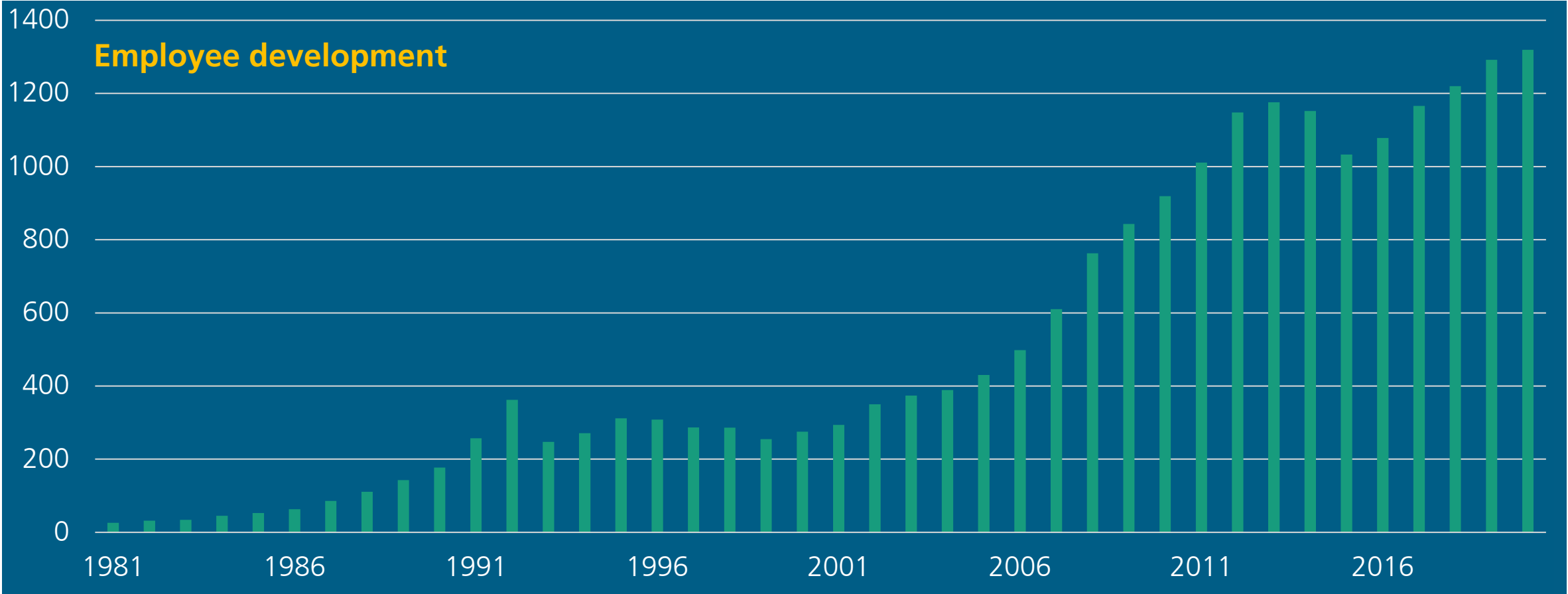
Inverter

## 2001: The New Site in Heidenhofstraße

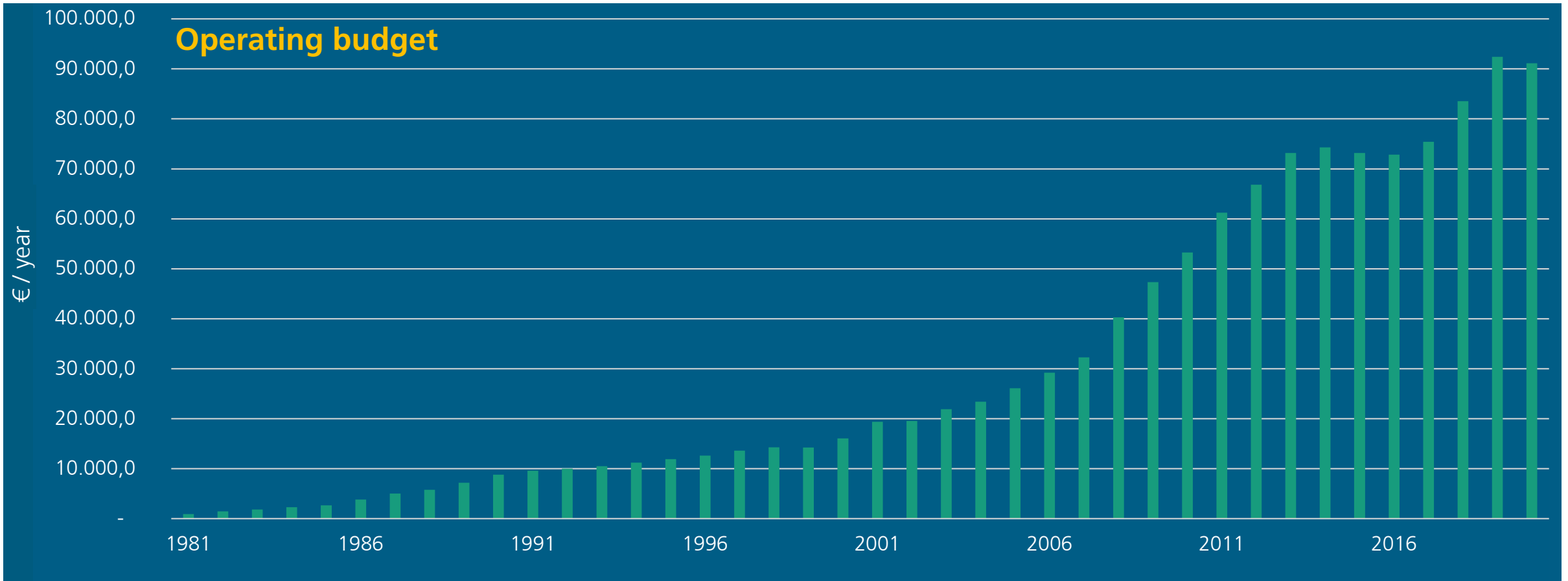




# 2021: 40 Years of Research for a Solar Energy System in Freiburg



# 2021: 40 Years of Research for a Solar Energy System in Freiburg



# Fraunhofer Institute for Solar Energy Systems ISE 2023



## Institute Directors:

Prof. Dr. Hans-Martin Henning

Prof. Dr. Andreas Bett

Employees ca. 1400

Budget 2022 €120.6 million

Founded in 1981

## Photovoltaics

Silicon Photovoltaics

III-V and Concentrator Photovoltaics

Perovskite and Organic Photovoltaics

Photovoltaic Modules and Power Plants

## Energy Efficient Buildings

Solar Thermal Power Plants and Industrial Processes

Hydrogen Technologies and Electrical Energy Storage

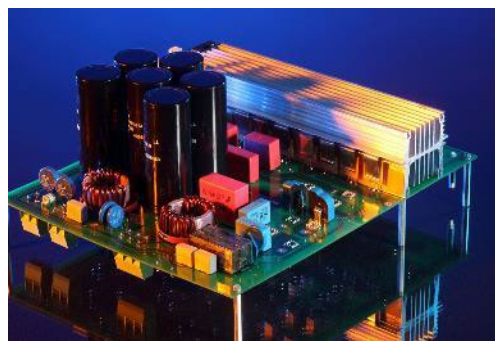
Power Electronics, Grids and Smart Systems

# Research Topics at the Fraunhofer ISE

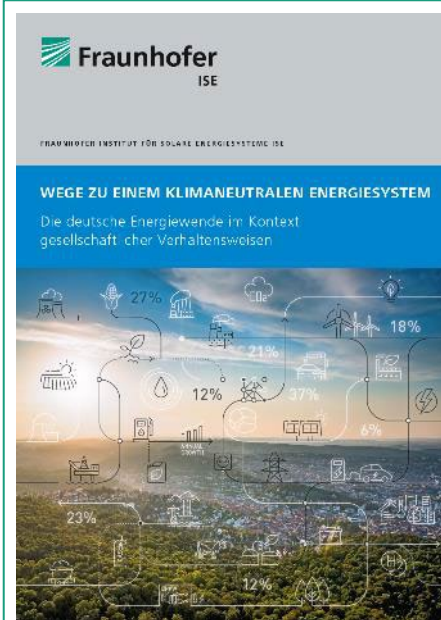
## A Few Examples



Integrated  
Photovoltaics



Inverter,  
world record 99,03%



REMod –  
a renewable energy  
system model to  
simulate cost-  
optimized paths to  
reach goals



III-V Solar Cell  
(several world records)



Hydrogen station

# Key Topics 2023

Important Strategic Pillars of our Research Activities



**Integrated  
Photovoltaics**



**Tandem  
Photovoltaics**



**Heat Pumps**



**Stationary Battery  
Storage**

# PV Application and Adapted Module Technology

## Integrated Photovoltaic

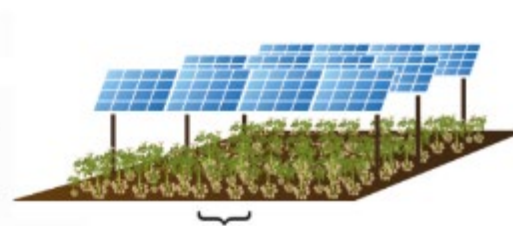


# Dual Use of Land

## Agrivoltaics



**100% Potatoes and 100% Solar Power**



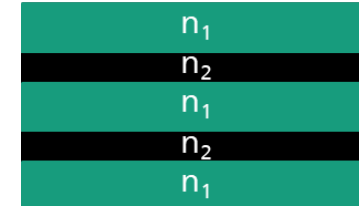
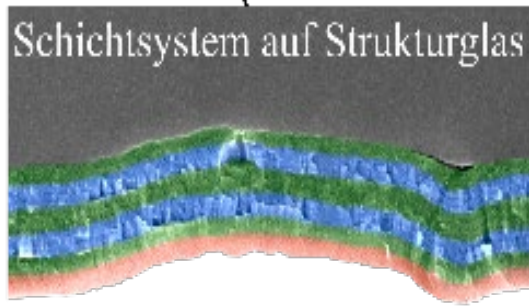
**103% Potatoes and 83% Solar Power  
→ 186% Land Use Efficiency**



# Facade Integration

## Integration into Existing Areas

- Solar cells are no longer visible!
- Patented technology



MorphoColor





# We Already Use the Sun in Many Places

But: More Has to Come!

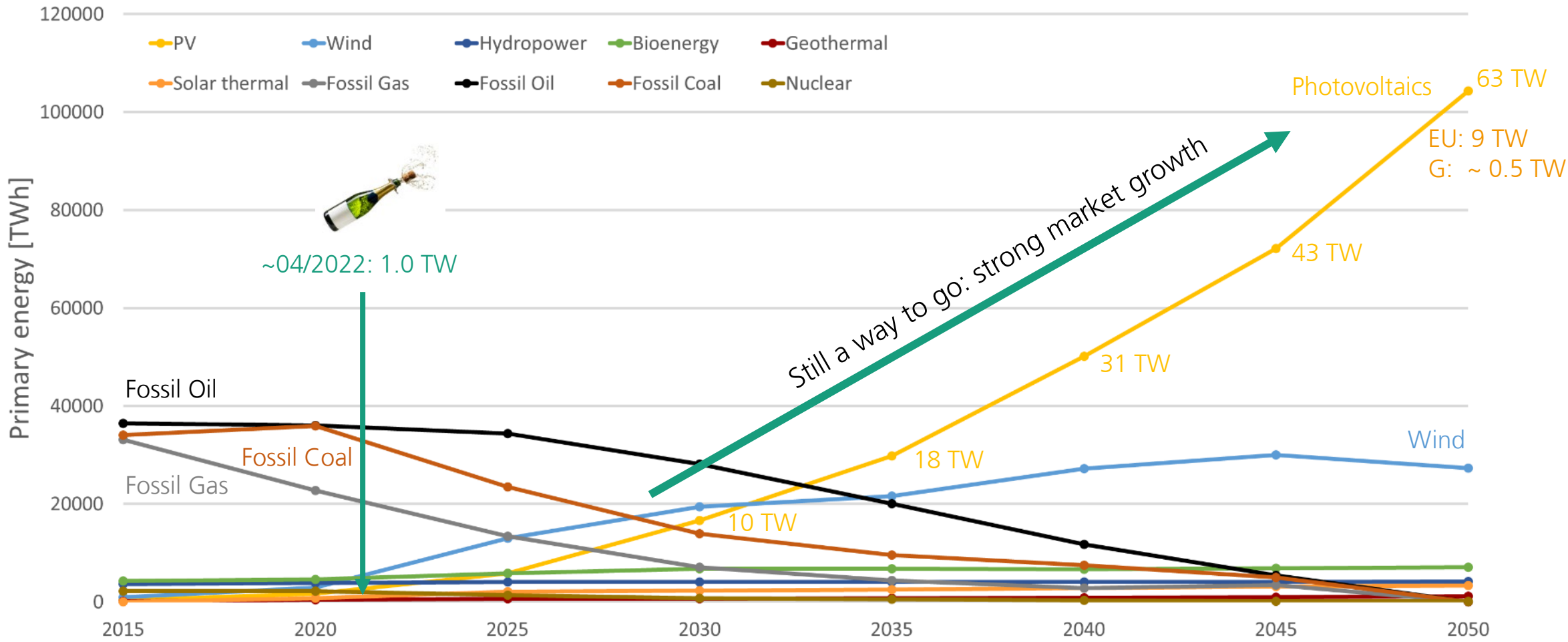


<https://www.memodo.de/blog/floating-pv/>

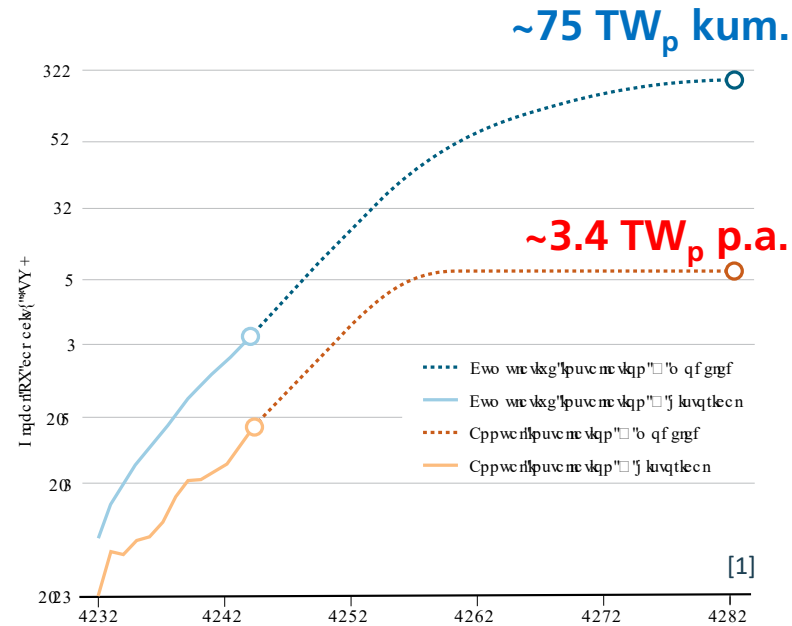
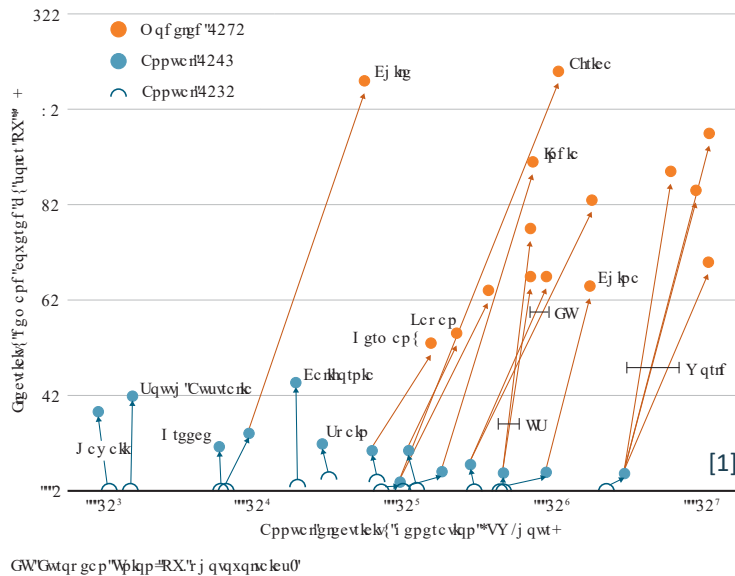


# Transformation of the Global Energy Supply to be CO<sub>2</sub>-free in 2050

Market: Photovoltaic is Needed in Huge Quantities!



# Science: PV Towards the Multi-Terawatt Age



## Goals 2050

- ~75 TW<sub>p</sub> global cumulated PV-capacity; ~3.4 TW<sub>p</sub> adding per annum
- Needs of material and resources for PV

How we organize this increase in a “sustainable” manner?

## POLICY FORUM

### RENEWABLE ENERGY

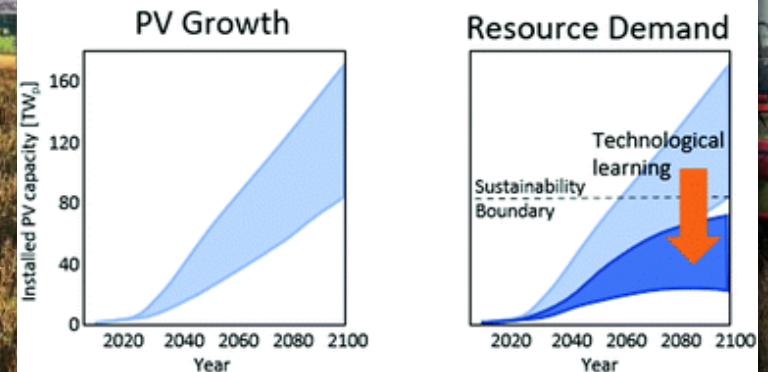
# Photovoltaics at multi-terawatt scale: Waiting is not an option

25% annual PV growth is possible over the next decade

By Nancy M. Haegel, Pierre Verlinden, Marta Victoria, Pietro Altermatt, Harry Atwater, Teresa Barnes, Christian Breyer, Chris Case, Stefaan De Wolf, Chris Deline, Marwan Dhamrin, Bernhard Dimmler, Markus Gloeckler, Jan Christoph Goldschmidt, Brett Hallam, Sophia Haussener, Burkhard Holder, Ulrich Jaeger, Arnulf Jaeger-Waldau, Izumi Kaizuka, Hiroshi Kikusato, Benjamin Kroposki, Sarah Kurtz, Koji Matsubara, Stefan Nowak, Kazuhiko Ogimoto, Christian Peter, Ian Marius Peters, Simon Philipps, Michael Powalla, Uwe Rau, Thomas Reindl, Maria Roumpani, Keiichiro Sakurai, Christian Schorn, Peter Schossig, Rutger Schlatmann, Ron Sinton, Abdelilah Slaoui, Brittany L. Smith, Peter Schneidewind, BJ Stanbery, Marko Topic, William Tumas, Juzer Vasi, Matthias Vetter, Eicke Weber, A. W. Weeber, Anke Weidlich, Dirk Weiss, Andreas W. Bett

## Technological learning for resource efficient terawatt scale photovoltaics

Jan Christoph Goldschmidt, <sup>ID</sup> <sup>a</sup> Lukas Wagner, <sup>ID</sup> <sup>a</sup> Robert Pietzcker <sup>ID</sup> <sup>b</sup> and Lorenz Friedrich <sup>ID</sup> <sup>a</sup>



Do not forget:  
The Sun powers the world!

$1,5 \cdot 10^{18}$  kWh/Jahr  
10.000 times more than  
the world energy demand





Thanks for attention  
Contact

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