



Photovoltaik – auf dem Weg zur wichtigsten Stromquelle weltweit?

Wer war Edmond Becquerel (1820 – 1891)?

MÉMOIRES LUS.

Mémoire sur les effets électriques produits sous l'influence des rayons solaires; par M. EDMOND BECQUEREL.

§ 1^{er}. *Action de la radiation sur les lames métalliques.*

« Dans le dernier Mémoire que j'ai eu l'honneur de présenter à l'Académie, dans sa séance du lundi 29 juillet 1839, je me suis attaché à mettre en évidence, à l'aide des courants électriques, les réactions chimiques qui ont lieu au contact de deux liquides, sous l'influence de la lumière solaire. Le procédé que j'ai employé nécessitait l'emploi de deux lames de platine, en relation avec les deux extrémités du fil d'un multiplicateur très sensible et qui plongeaient chacune dans une des dissolutions superposées. Or comme ces deux lames éprouvaient elles-mêmes les effets de la radiation, il a dû en résulter des phénomènes composés, dont je vais m'occuper dans ce nouveau Mémoire. On sera à même ensuite de faire la part de chacun des effets produits.



Comptes Rendues de l'Académie des Sciences
6 (1839) 561

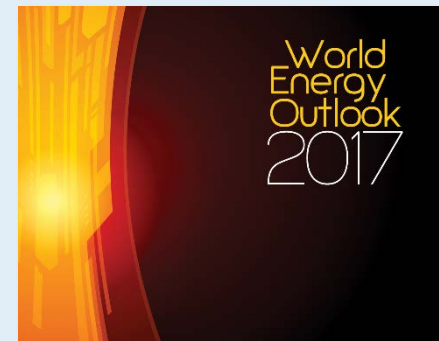


World Energy Outlook 2017

Tipping the energy world off its axis

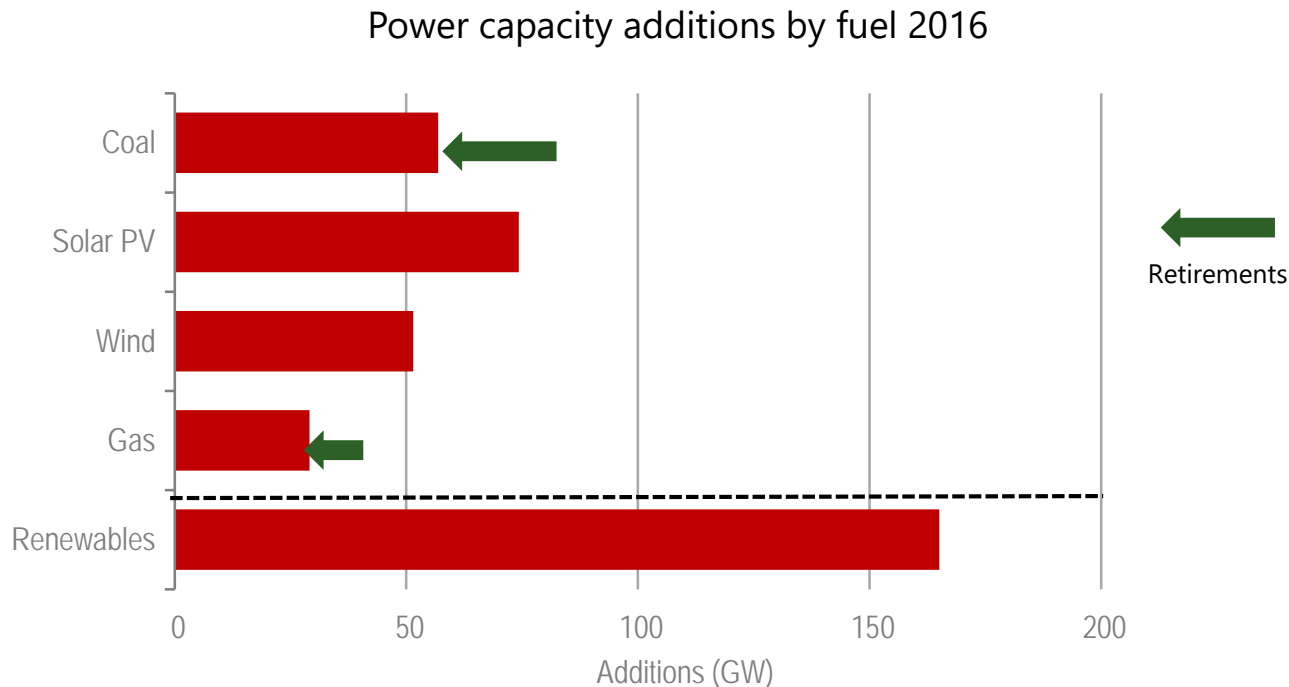


- Four **large-scale upheavals** in global energy are underway:
 - The **United States** is turning into the undisputed global leader for oil & gas
 - **Solar PV** is on track to be the cheapest source of new electricity in many countries
 - **China's** new drive to "make the skies blue again" is recasting its role in energy
 - The future is **electrifying**, spurred by cooling, electric vehicles & digitalisation
- There are many possible pathways ahead & many potential pitfalls if governments or industry misread the signs of change



Fatih Birol, Executive Director IEA

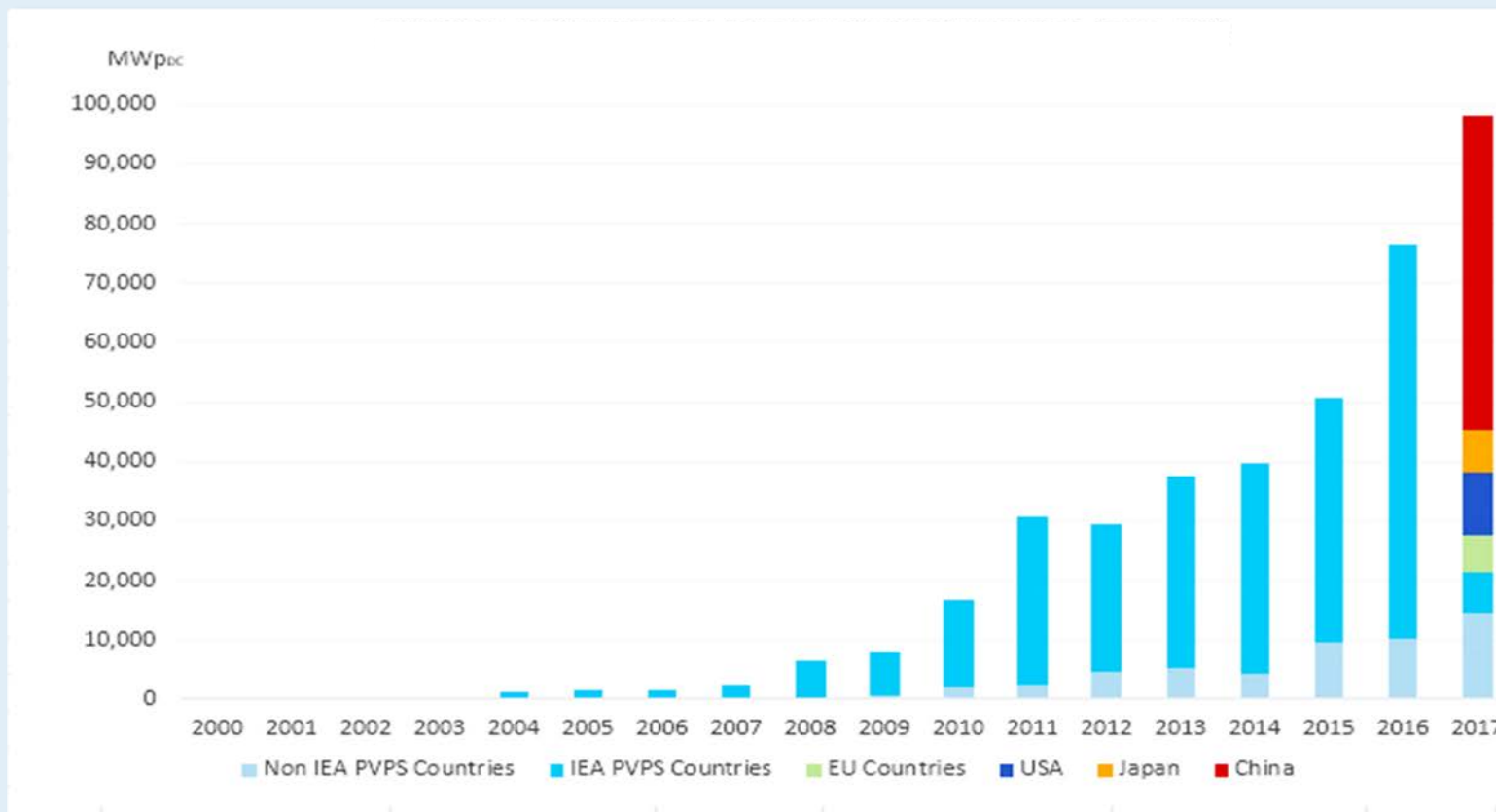
2016 – Renewables hitting new records driven by solar PV



For the first time a single renewable fuel became the largest source of net capacity growth, while all renewables provided an all-time record two thirds of global net capacity additions

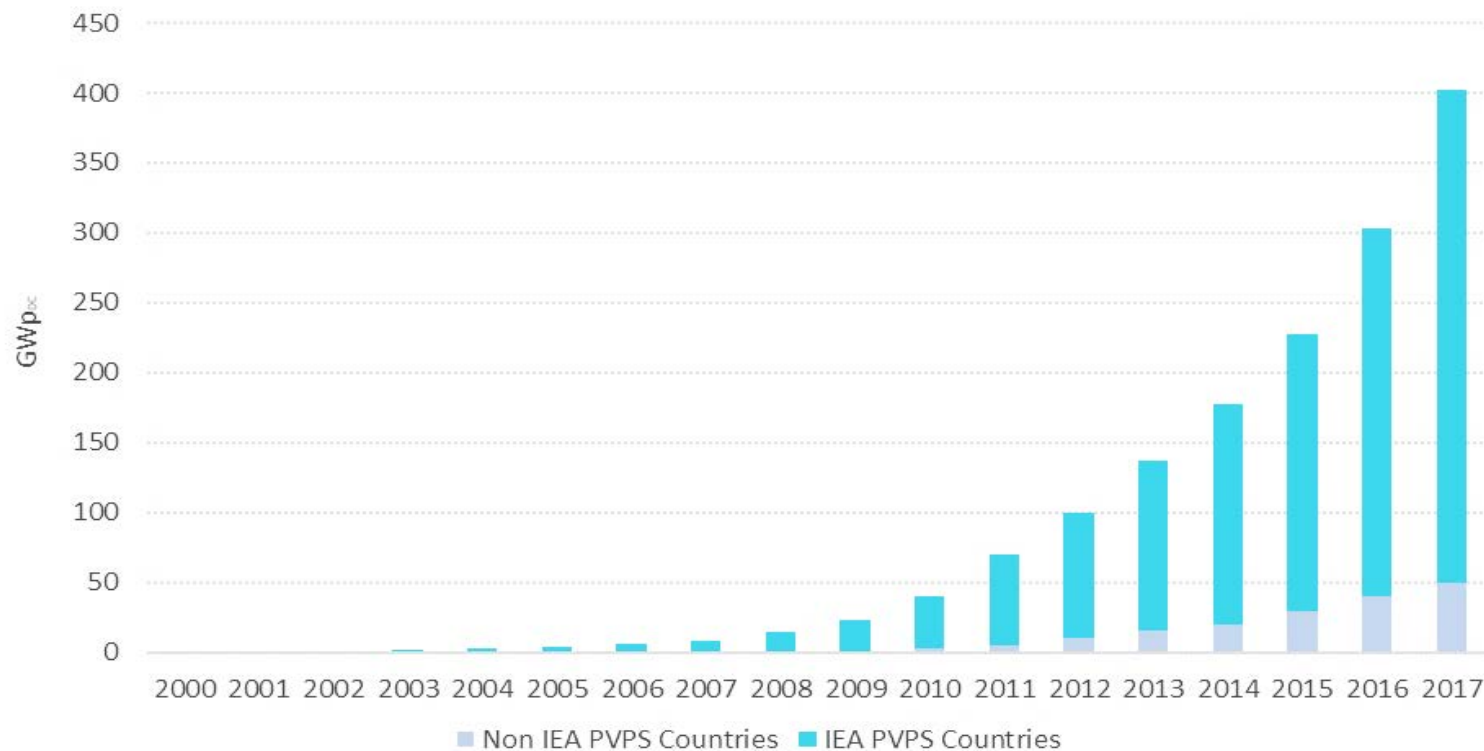


Photovoltaik Markt weltweit



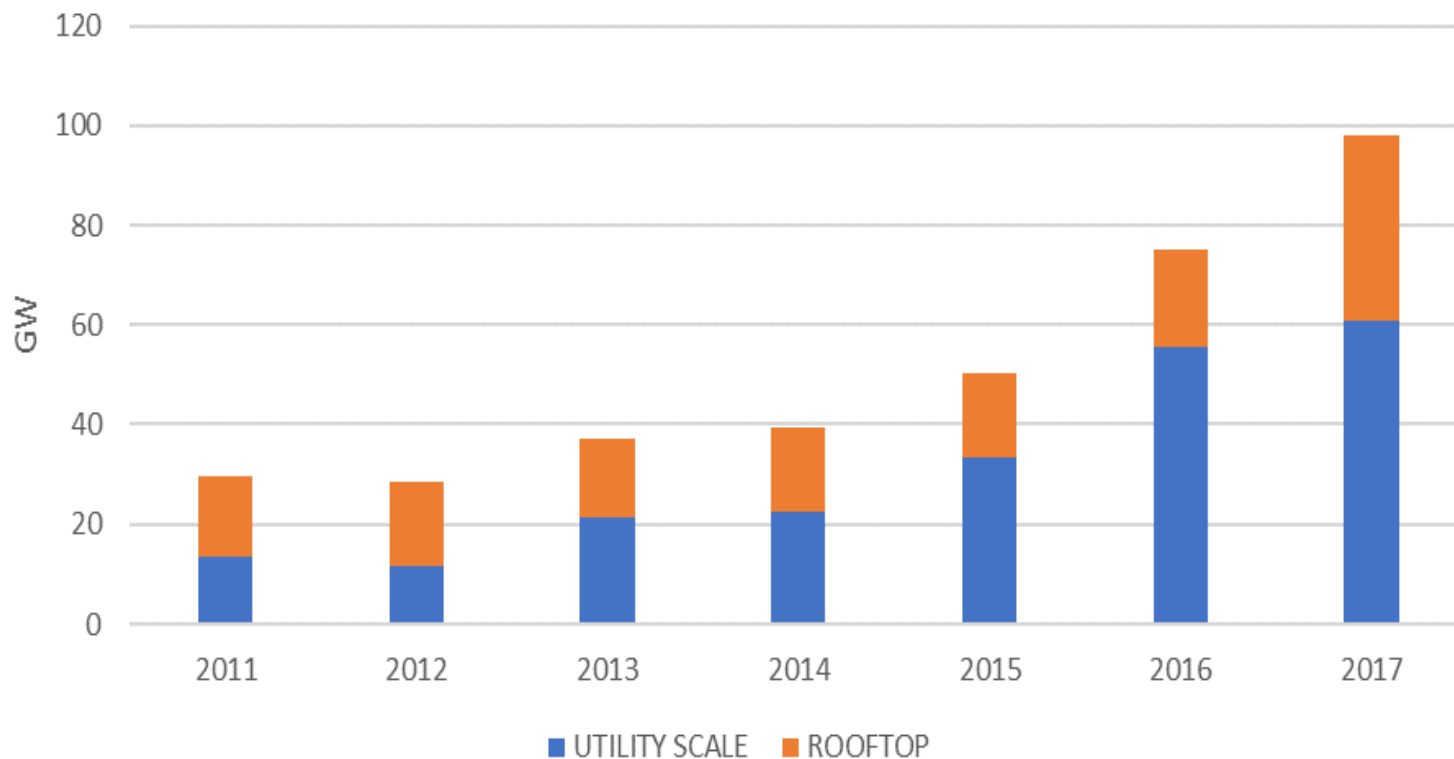


Photovoltaik Markt weltweit





Photovoltaik Markt weltweit





Meilensteine der Photovoltaik

Jahr	Jährliche Kapazität
1999	> 100 MW
2004	> 1 GW
2010	> 10 GW
...	
2017	98 GW

Jahr	Kumulierte Kapazität
1995	> 100 MW
2002	> 1 GW
2008	> 10 GW
2012	~ 100 GW
2017	402 GW

2021/2022	> 1 TW
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Kosten



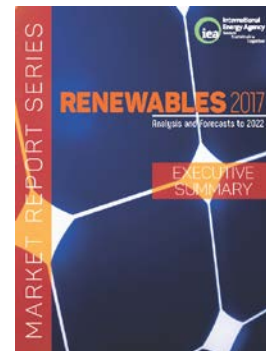
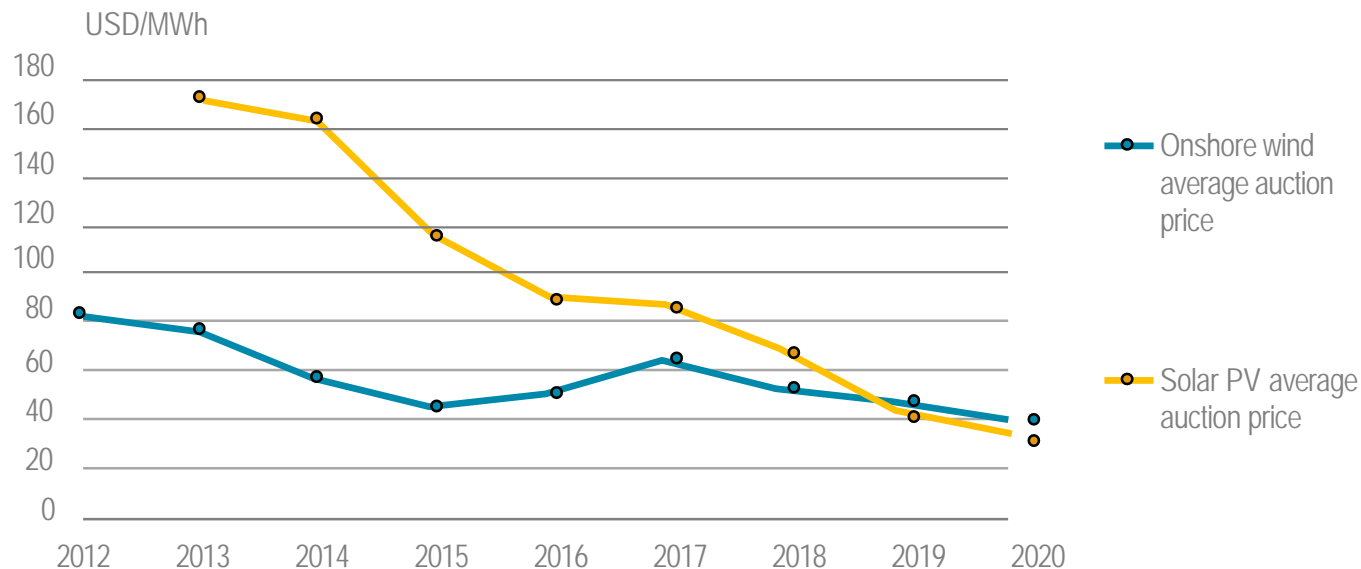


Kosten: Enorme Reduktion!

-75% über 10 Jahre,
2017: \approx 20 USD/MWh im besten Fall

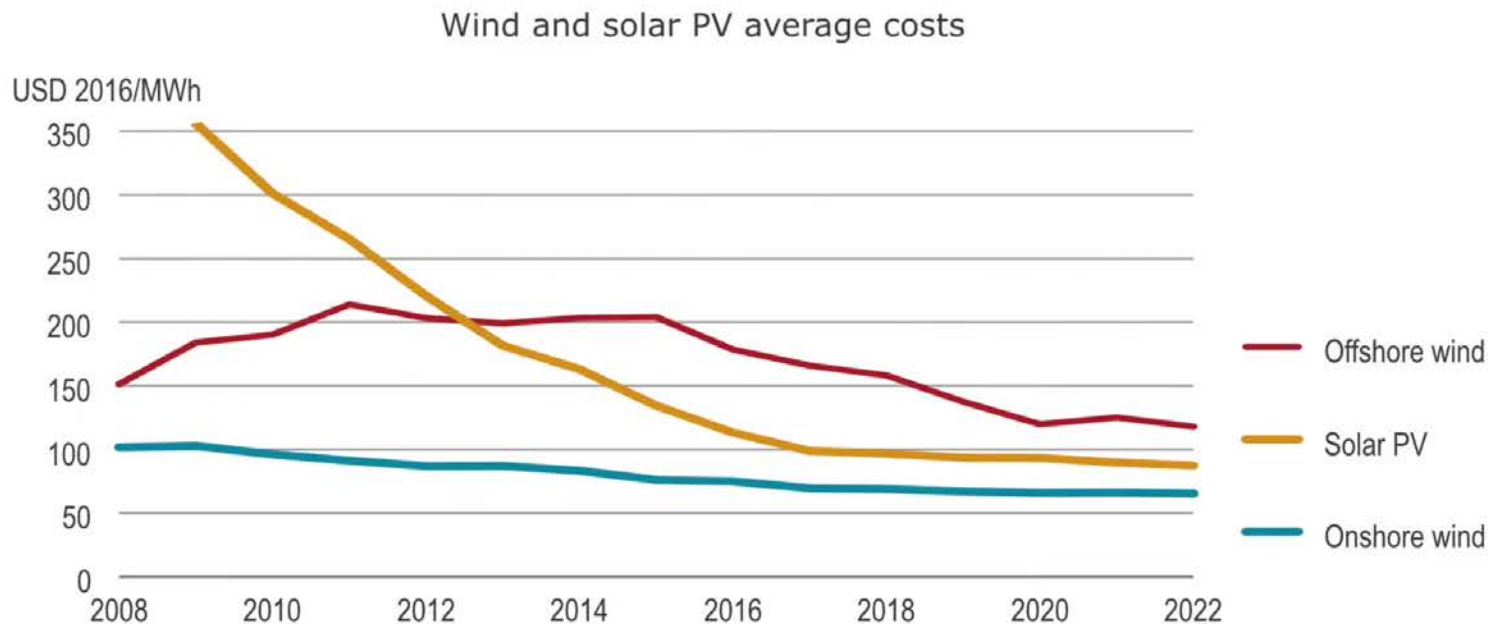
Competition driving costs down

Announced wind and solar PV average auction prices by commissioning date



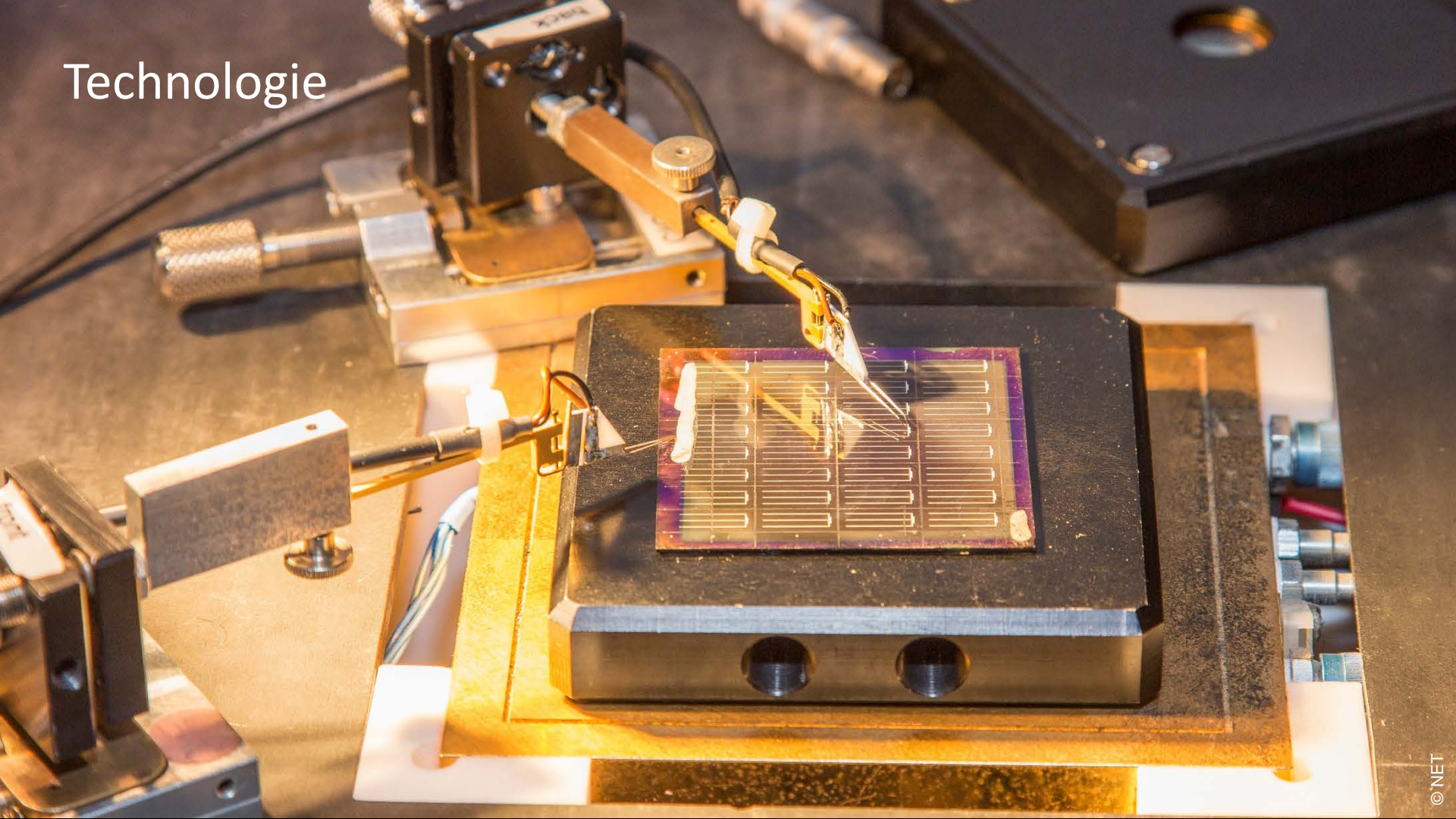
**Price discovery through competitive auctions effectively reduces costs along the entire value chain;
Auctions with long-term contracts will drive almost half of new capacity growth over 2017-22**

Wind and solar PV costs being driven down by competition



The cost of wind and solar PV have fallen sharply, with further reductions expected; cost-optimal integration requires interconnections, flexible generation, storage and demand response

Technologie



Technology: the various application fields

Powerpure

technologies for lowest cost solar electricity

Elegance and architecture

transforming building and cities with solar

Smart

intelligent E-management, efficiency in building, storage, renewable

Explore

customized PV products from the water to the air

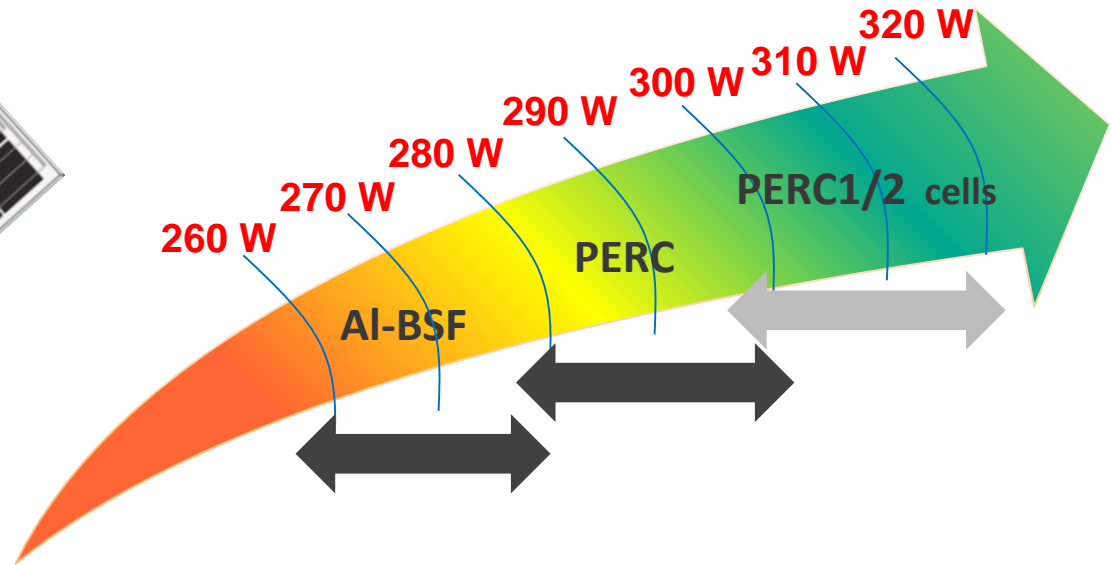
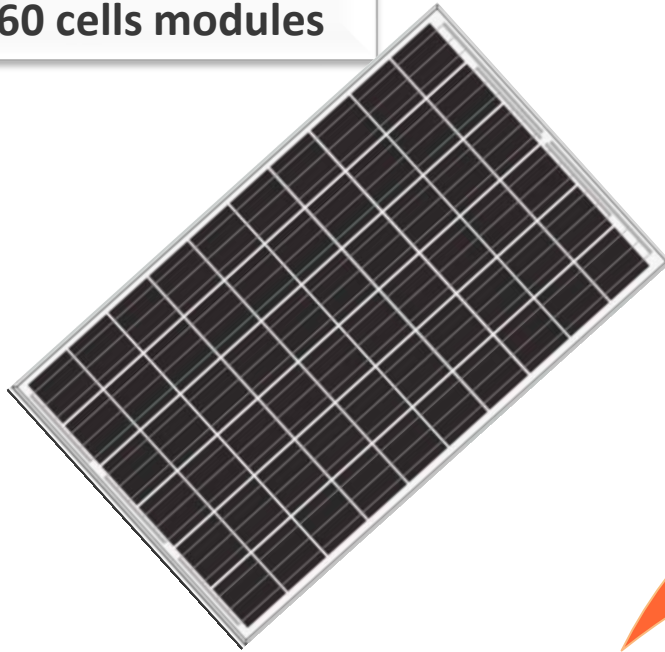
E-tonomy

energy scavengers and ubiquitous power sources

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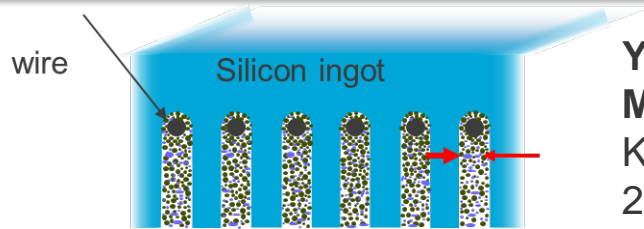
The 7 trends which will make PV even cheaper, and greener

Monocrystalline
60 cells modules

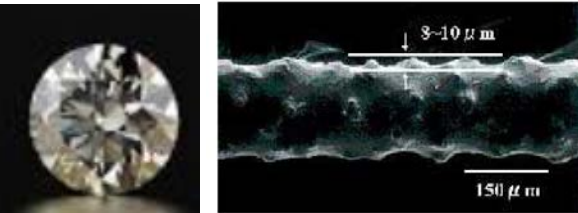


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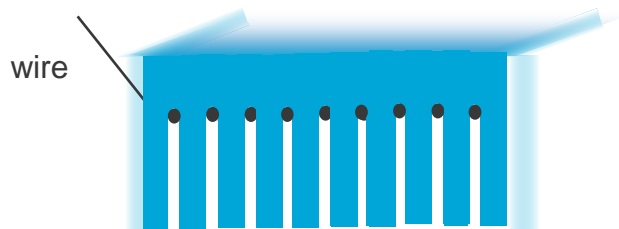
The 7 trends which will make PV even cheaper, and greener



Yesterday
Multi-wire sawing, SiC particles
Kerf loss ~ 150 microns
200 microns wafers



Today
diamond wire for mono
Kerf loss 60-70 microns
180 microns wafers → 45% more !



180 microns p-type mono → 63cts/wafer
N-type → 68cts/wafer

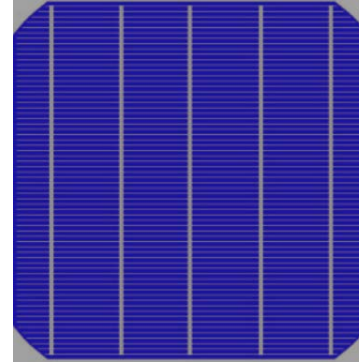
180 microns Wafer
12-13 cts/Watt, 3.5-4 g of Si/Wp



Payback-time !

Powerpure

The 7 trends which will make PV even cheaper, and greener



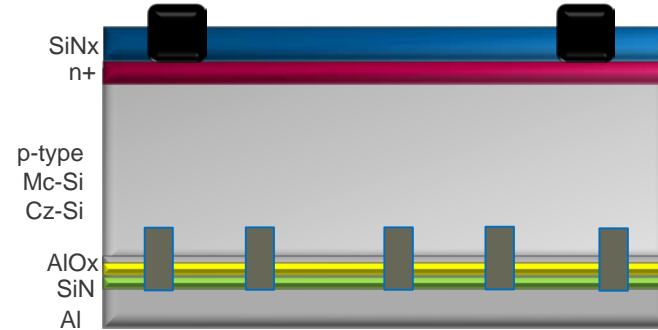
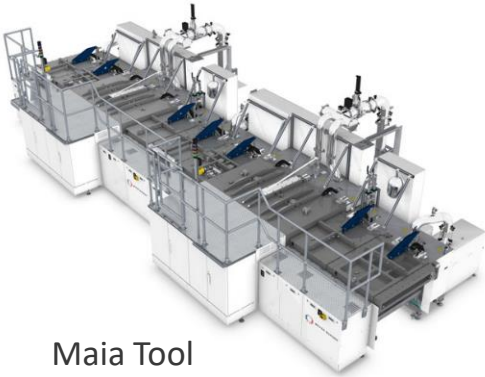
More busbars to save on the cost of screen-printed Ag lines



100 mg less of Ag per solar cell, 0.5% more power

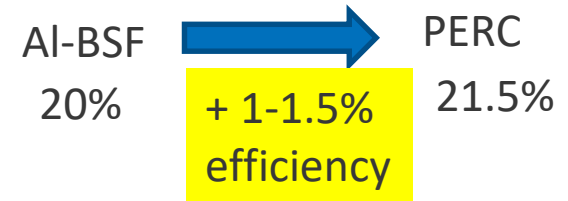
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Al-BSF cells is being replaced by PERC and other kinds of cells



PERC: local front and rear contact

- ++ higher current
- ++ higher voltage
- 2 additional process steps
- need better wafers



Si Heterojunction, n-Pert

Powerpure

The 7 trends which will make PV even cheaper, and greener



1-axis tracking

+ 20-30% energy, at +15-20%
initial system costs +
maintenance

- 5-10% LCOE reduction

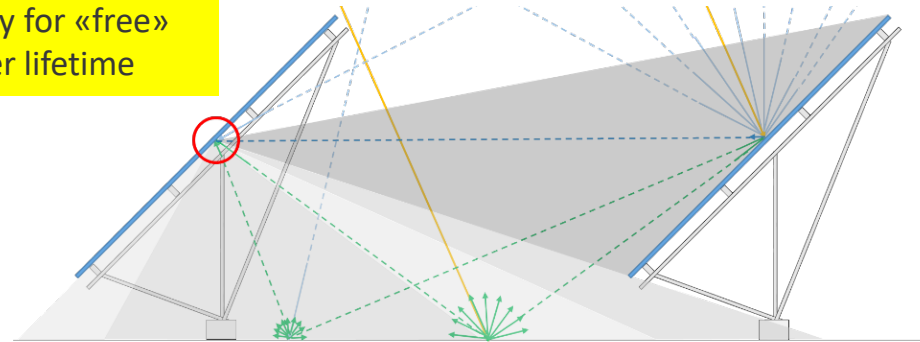
System voltage \rightarrow 1500 V
40 modules in series

- LCOE reduction



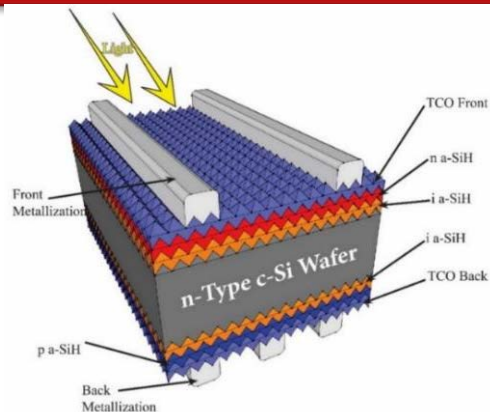
Bi-facial modules from glass-glass

- 15-25% more energy for «free»
- Longer lifetime



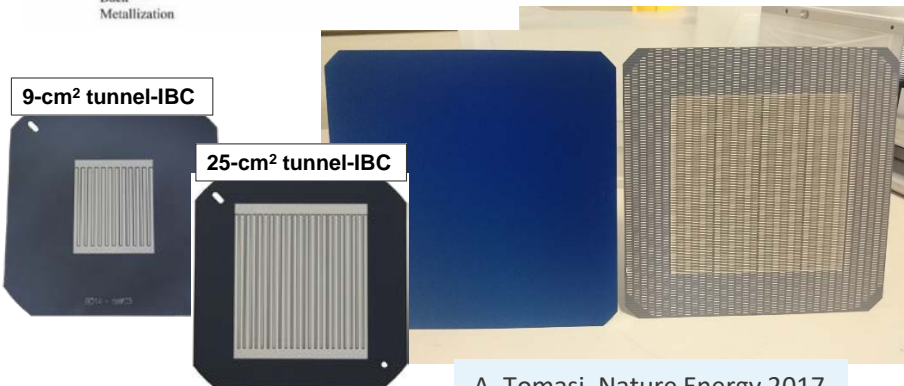
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technologies for lowest cost solar electricity: some focus at CSEM/EPFL



- Heterojunction (24.1%)
- Back-contacted heterojunction (24.1%)
- Lean process for Both sides Passivating contacts devices (22.6%) (PERC upgrade)

See talk by M. Despeisse
And various posters



A. Tomasi, Nature Energy 2017

- Few process steps
- High(er) efficiency
- High energy yield
- Work with 100 micron wafers
- Bifacial

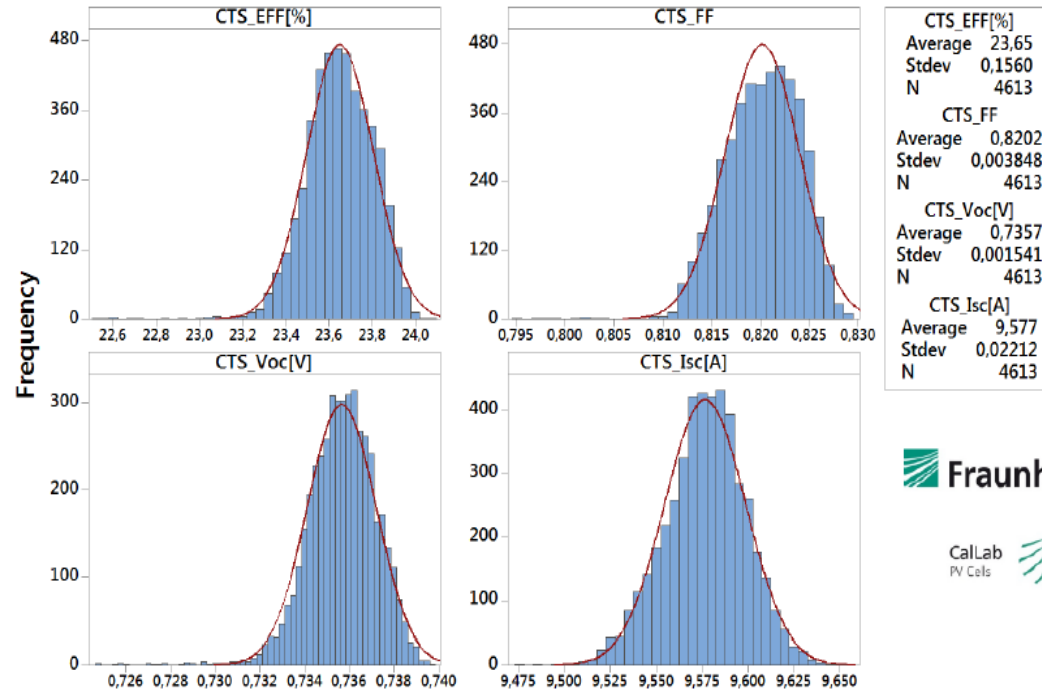
Result from R&D Golden Run



MEYER BURGER

Thanks to
B. Bonnet-
Aymar

Meyer Burger (Germany) AG- HJT Demoline_ R&D Golden Run 2017



- R&D activities were integrated in 'Golden Run': pyramid engineering (+0.15%), fine line printing (+0.2%) and new PECVD concept (+0.2%, -25% CaPex)
- $\eta_{\text{average}} = 23.65\%$ **GT_intrinsic**, = 22.85% **GT_effective**
- Champion solar cell efficiency $\eta = 24,02\%$ **GT_intrinsic** (Fraunhofer ISE based calibration)

MB demo lines
>> 1000 wafers

Average 23.65%

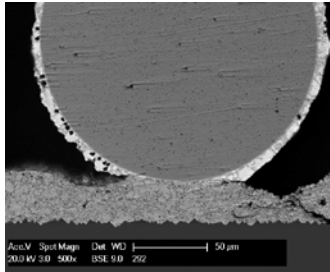
Certified 24.02%
Busbarless
(BB equivalent 23.2%)
244 cm²

**Tight very high efficiency
Production possible**

From 3 to 5 to Multi-wire interconnection: further reduce Ag costs



- Thicker wire
- No-more indium
- More transparent polymers
- Much less Ag fingers (or Cu)



*(SWCT™) to play a key role in REC
Group's cutting-edge high efficiency
solar module technology
02/12/2018*

UV Transparent SWCT with In-free wires



MEYER BURGER



March 2018
IEC 61215:2016 and IEC 61730:2016



Meyer Burger AG
Schorenstrasse 39
3645 Gwatt (Thun)
Switzerland

Dipl.-Ing. Andreas Cox
Tel. +49 221 800-2870
Fax. +49 221 800-1350
Mail. cox@de.tuv.com
Web. www.tuv.com/de
Cologne, 14 March 2018

Declaration on IEC testing
No. 21240408-2

Manufacturer: Meyer Burger AG
Schorenstrasse 39
3645 Gwatt (Thun)
Switzerland

PV-modules: Meyer Burger SmartWire PV modules, consisting of the SmartWire substrate foil, copper wires with alloy coating and other materials as laid down in project 21240408.

Herewith it is declared, that above listed PV-modules were tested at TÜV Rheinland acc. IEC 61215:2016 and IEC 61730:2016. All laboratory tests were passed acc. to the regulations of the standards.

Business Field Solar Energy

L. V.

Dipl.-Ing. J. Jankisch

L. A.

Dipl.-Ing. A. Cox

Power gain up to 2% with cost reduction of foil of 20%

Reliability (HJT):

PTC: < 1% degradation after 3xIEC

DH: < 2% degradation after 2xIEC

Reliability (PERC):

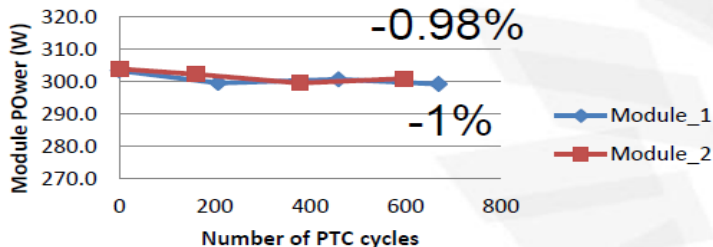
PTC: ~ 1% degradation after 3xIEC

DH: < 2% degradation after 2xIEC

Reliability (PERT):

PTC: < 1% degradation after 2xIEC

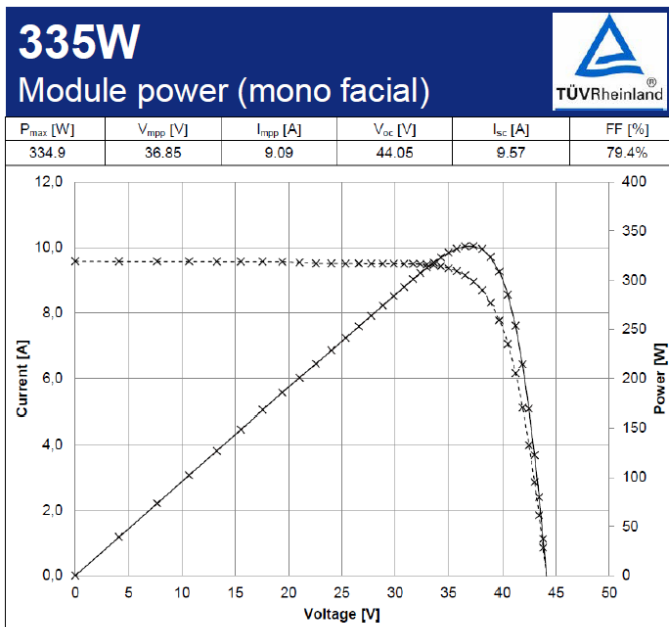
PERC GBS Gen4



New record, 60 cells modules (Meyer Burger EPFL-CSEM-CEA) Regular cell spacing, white back-ground

Thanks to
MBT team

335W Champion Module –

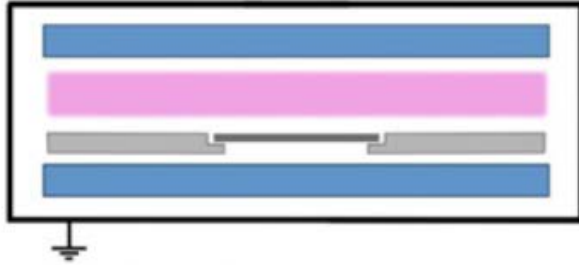


Up to
92.6%
bifaciality

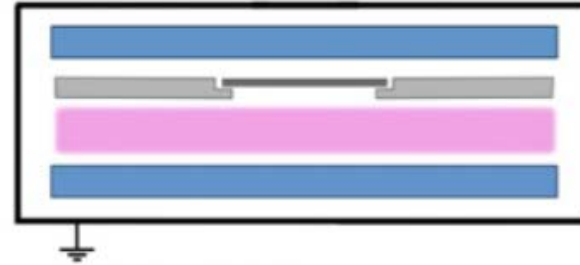




Advanced PECVD reactor for a-Si depositions



Top side deposition Mirror



Bottom side deposition Mirror



Minimizing the handling



Powerpure

Recent exemples market application

Hevel completes first heterojunction-based PV power plants in Russia

By Mark Osborne | Sep 20, 2017 1:11 PM BST | 0

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Sept 2017 Hevel runs 160 MW lines in Russia based on Mix of Oerlikon-Meyer Burger technologies

INDEOtec to supply Saudi Arabia's KAUST with heterojunction solar cell deposition system

By Mark Osborne | Mar 03, 2017 9:52 AM GMT | 0

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Summer 2017
ISE and Kaust
2017 customers of
Neuchâtel's
Indeotec



OUR TECHNOLOGIES ▾

OUR PRODUCTS AND SYSTEMS ▾

10/23/2017

Meyer Burger awarded major strategic contract for around CHF 45 million by an Italian photovoltaic manufacturer for bifacial Heterojunction lines enabling production capacity of up to 200MW

Meyer Burger's high performance Heterojunction (HJT) solar cell coating technology has been selected for the installation of a manufacturing line to produce bifacial Heterojunction solar cells in Catania, Italy. The contract volume is around CHF 45 million.

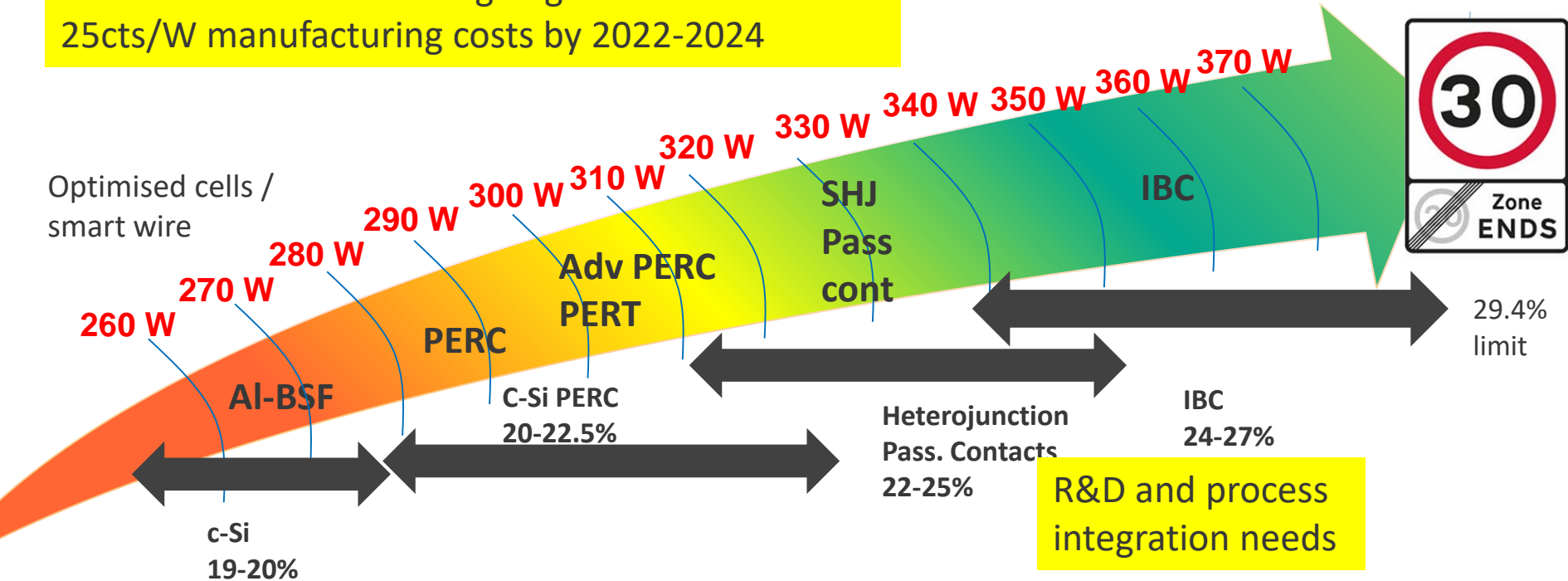
October 2017

3Sun/Catania is the buyer of 200 MW production lines from MB. 3Suns Leading H2020 Ampere Project with CSEM and EPFL and Meyer Burger

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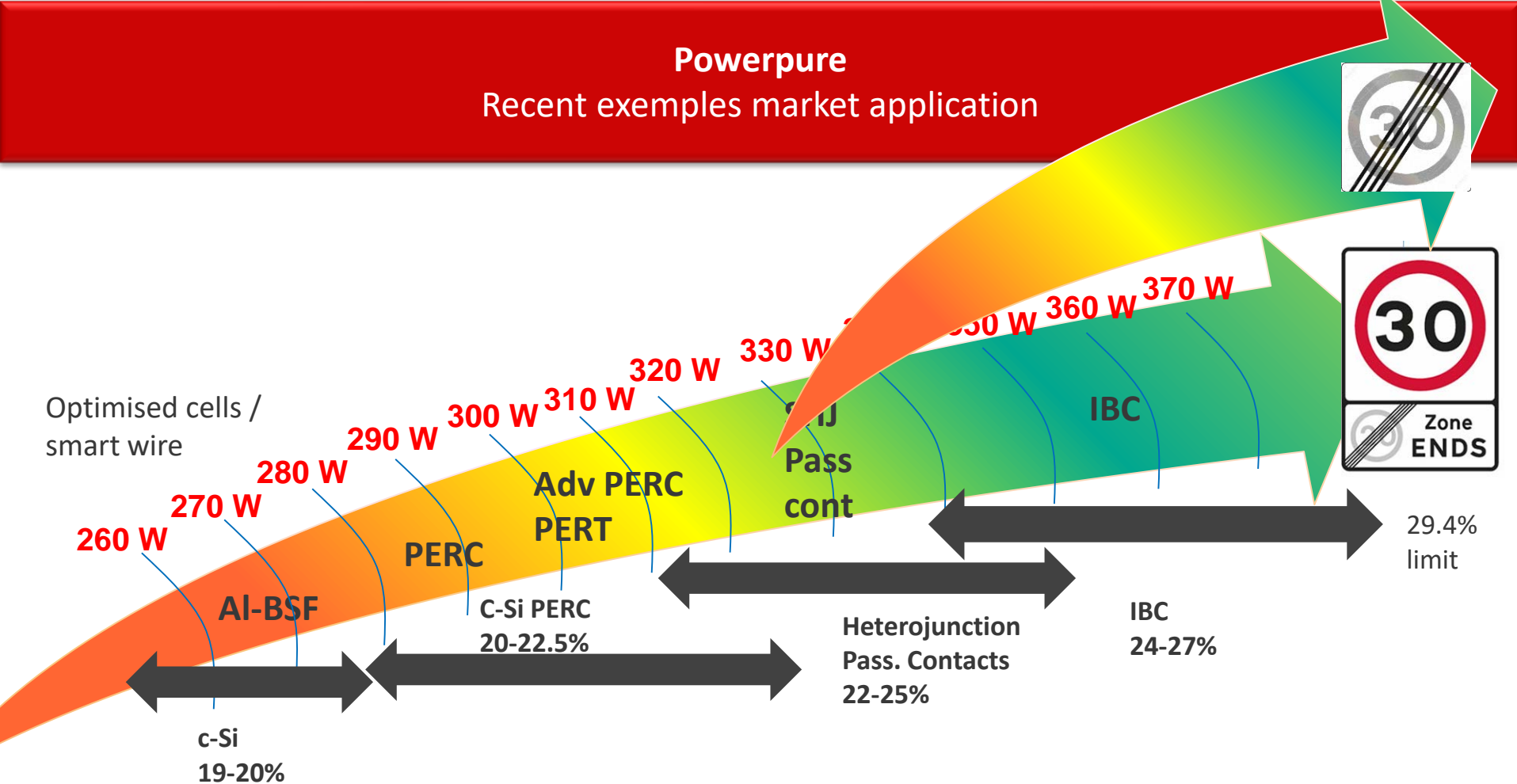
Recent exemples market application

Mainstream modules are going to 19-20%
25cts/W manufacturing costs by 2022-2024



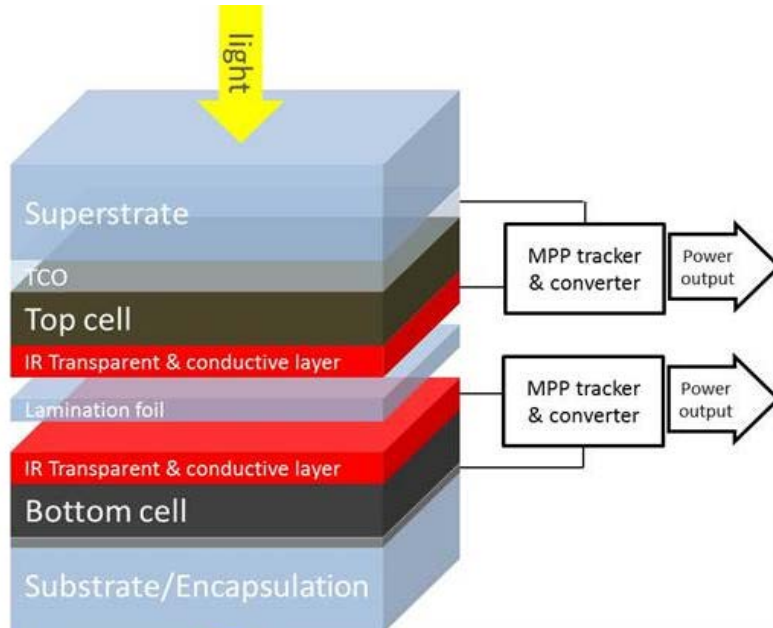
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Recent exemples market application



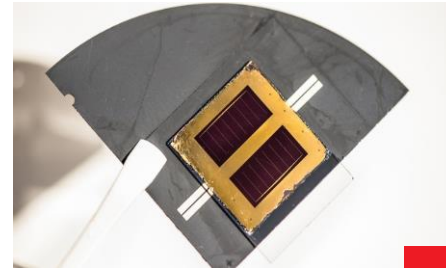
Powerpure : tomorrow

Examples of cutting edge research on multi-junctions/Si based

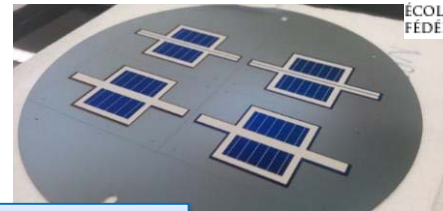


4 terminals 2 junctions III-V /c-Si tandem,

> 32.8 % Record du monde



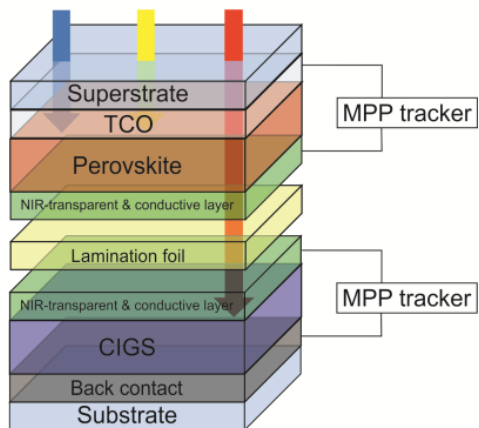
> 35.9 %
with 3
junctions



S. Essig et al. Nature Energy 2017

Perovskite for multi-junctions: potential low costs

Perovskite on CIGS, 4 terminal



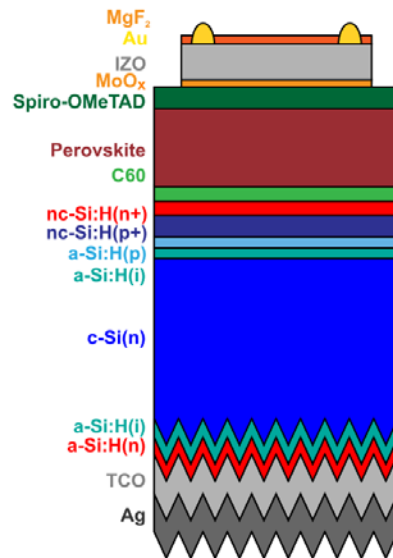
Potential
for 30%

22.7%
All thin film
Perovskite on CIGS

Fu Fan et al.



Perovskite on Silicon monolithic



25% certified, current
«record»



J. Werner et al.
F. Sahli et al.

Elegance and architecture

Transforming building and cities, renovating houses

Swiss Inso, Solaxess, Freesuns, designery, Solaxess, Megasol, Meyer Burger, Schweizer, Glass Troesch, Panotron,... + R&D institutues



Challenges:

- custom modules, easier to vary texture, colors
- Easy to mount, install
- Keep local manufacturing (micro-fabs)/content
- Reduce strongly all the other non-module costs in the installation
- More projects needed...

//////active
interfaces



Freesuns solar tiles /Colombier sur morges

Elegance and architecture

Transforming building and cities



Glass Troesch/ Fachhochschule Luzern



Swiss Inso/ Leso

Elegance and architecture

Transforming building and cities

- Based on polymer and module platform
- Technological support or transfert to companies



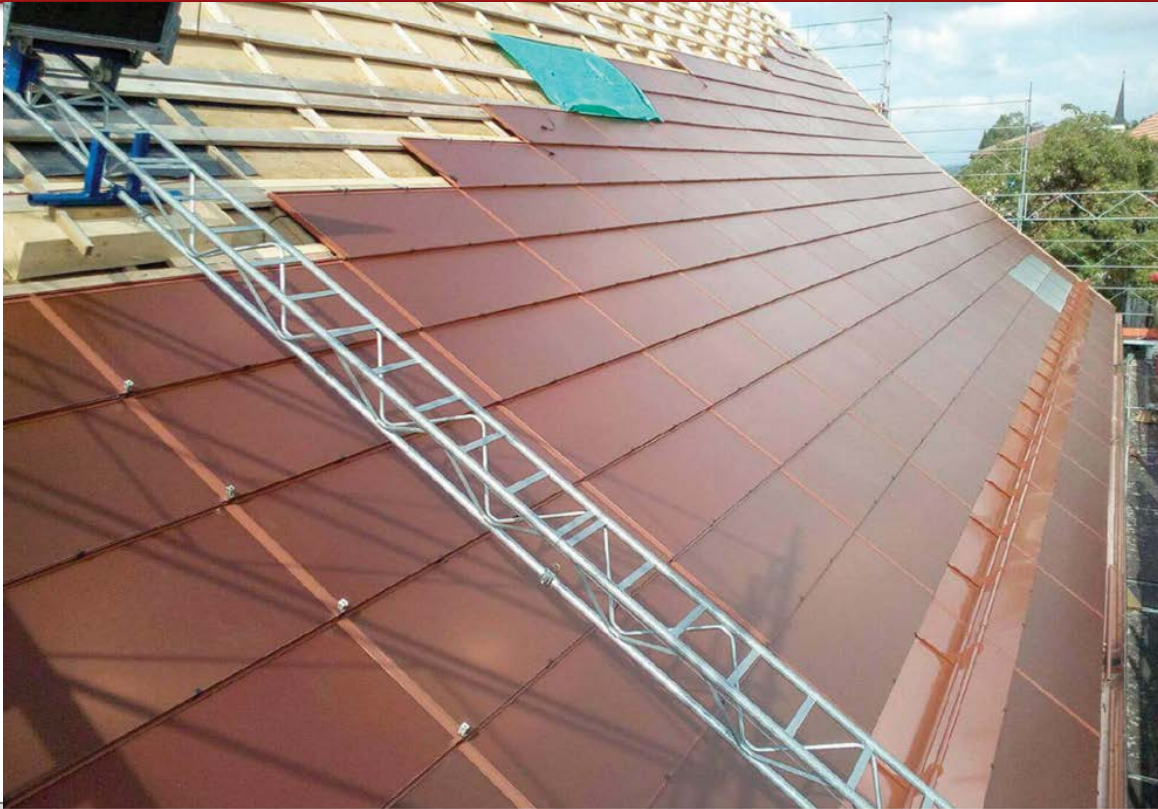
Manipulation of adhesion, temperature,
Creating color films,

White PV panels, together with Solaxess



Elegance and architecture

Transforming building and cities: new crystalline tiles in protected environment



*One of the Terra-cotta
Tones, with ISSOL, Solstis
Userhuus, SFOE*

Elegance and architecture

Transforming building and cities: new crystalline tiles in protected environment



*One of the Terra-cotta
Tones, with ISSOL, Solstis
Userhuus, SFOE*

Elegance and architecture

Transforming building and cities: new crystalline tiles in protected environment



*Modules with colored
meshes of a Swiss Supplier*

DSSC module from H-Glass

- Up-to where can you modify PV ?

The Kaleo project







Banque Cantonale Neuchâteloise





Banque Cantonale Neuchâteloise

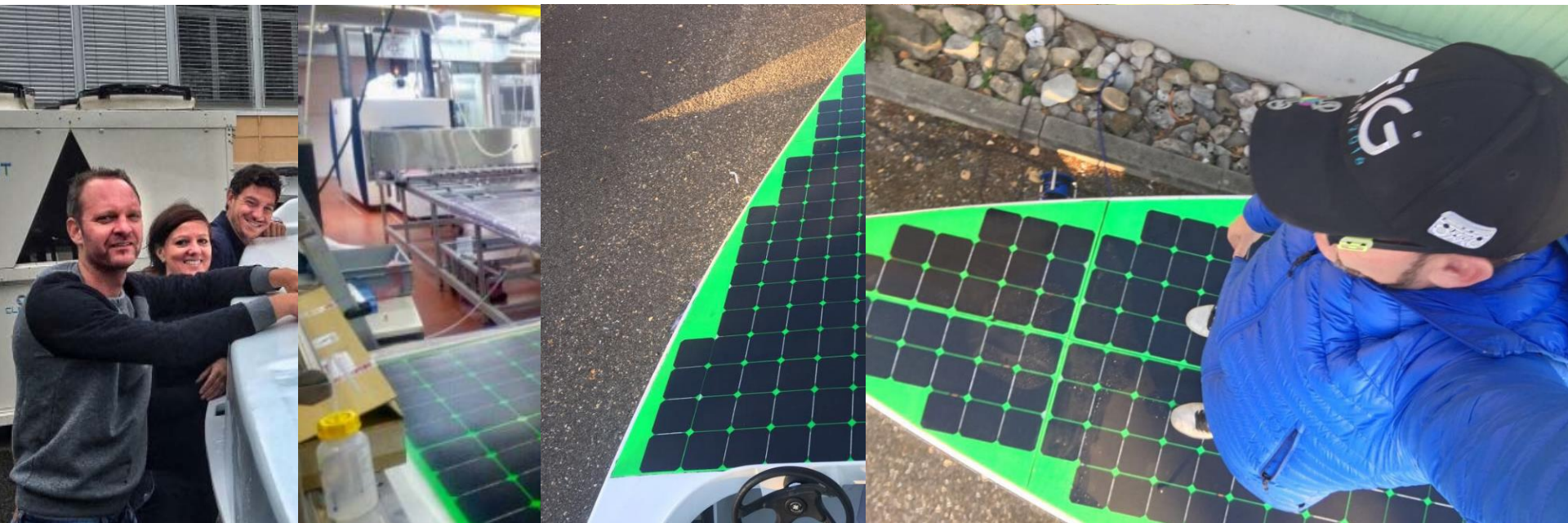


Kaleo with BCN

Explore customized PV products from the water to the air

- High-couture modules for competition boats

Artic solar with Anne Qéméré



Explore

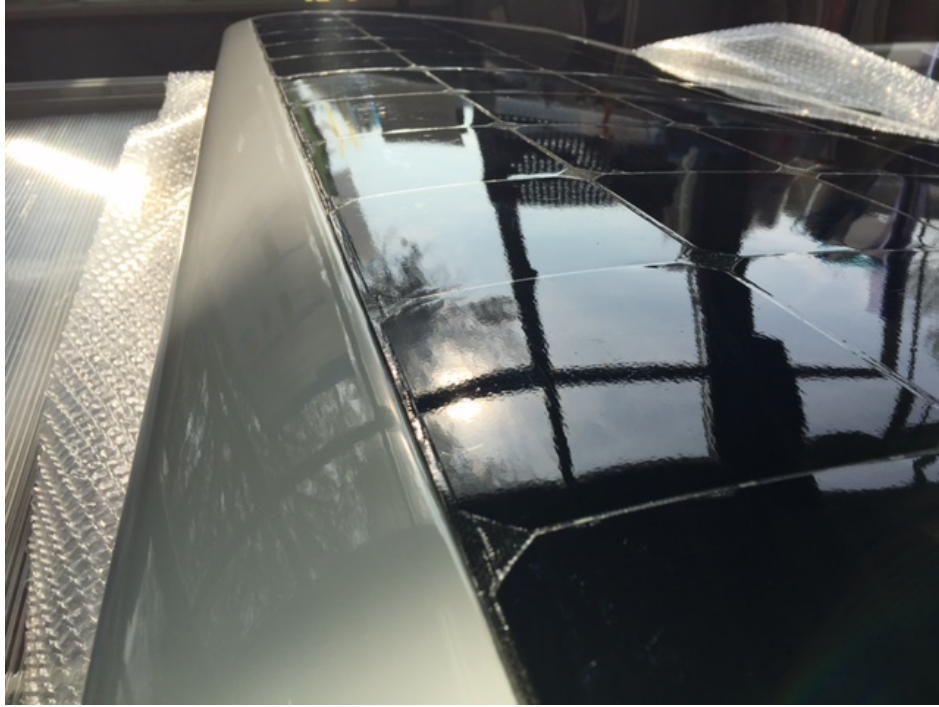
customized PV products from the water to the air

- Light weight specialty modules for terrestrial and space



Solarstratos first flight

Lightest weight



Technology

- No limits for PV to become by far the cheapest/most abundant source of electricity
- Beginning and not the end of the global PV market and technology developments
- Huge application potential
- Prepare now the solutions of the future
- Unique portfolio of expertise and technologies in CH



Jamais le soleil ne voit l'ombre

(The sun has never seen a shadow)

Léonard de Vinci

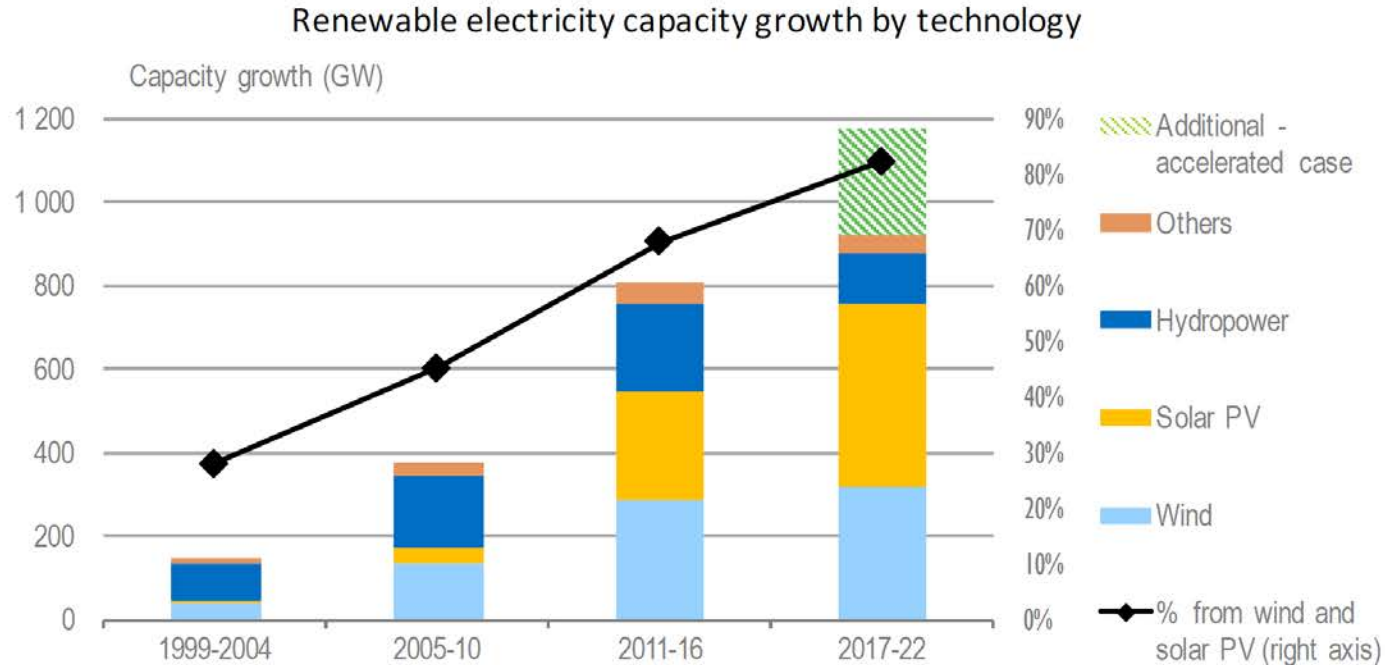
Solarstratos



Entwicklung der Photovoltaik

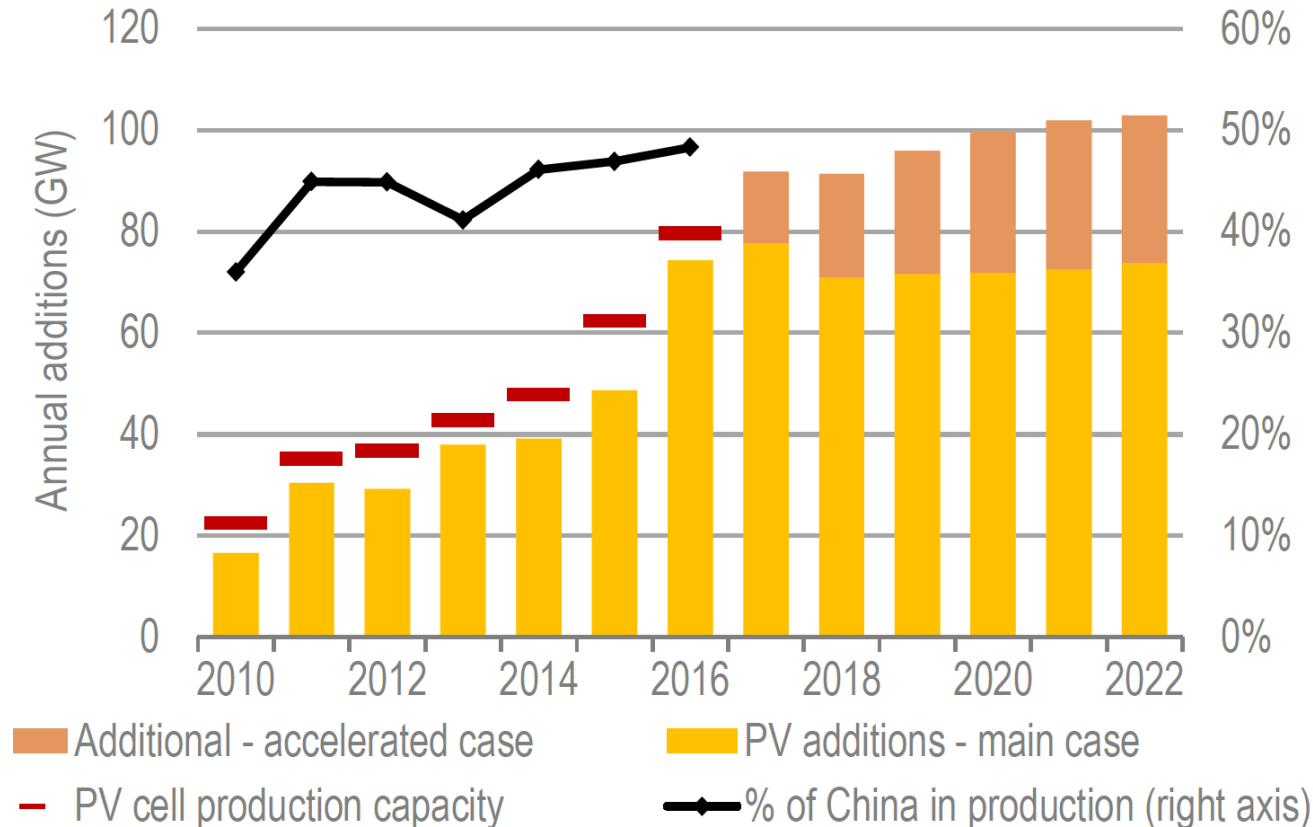
- Technisch: Evolution
stetige Weiterentwicklung
- Marktbezogen: Revolution
neue dynamische Märkte

Renewables growth more and more dependent on wind and solar



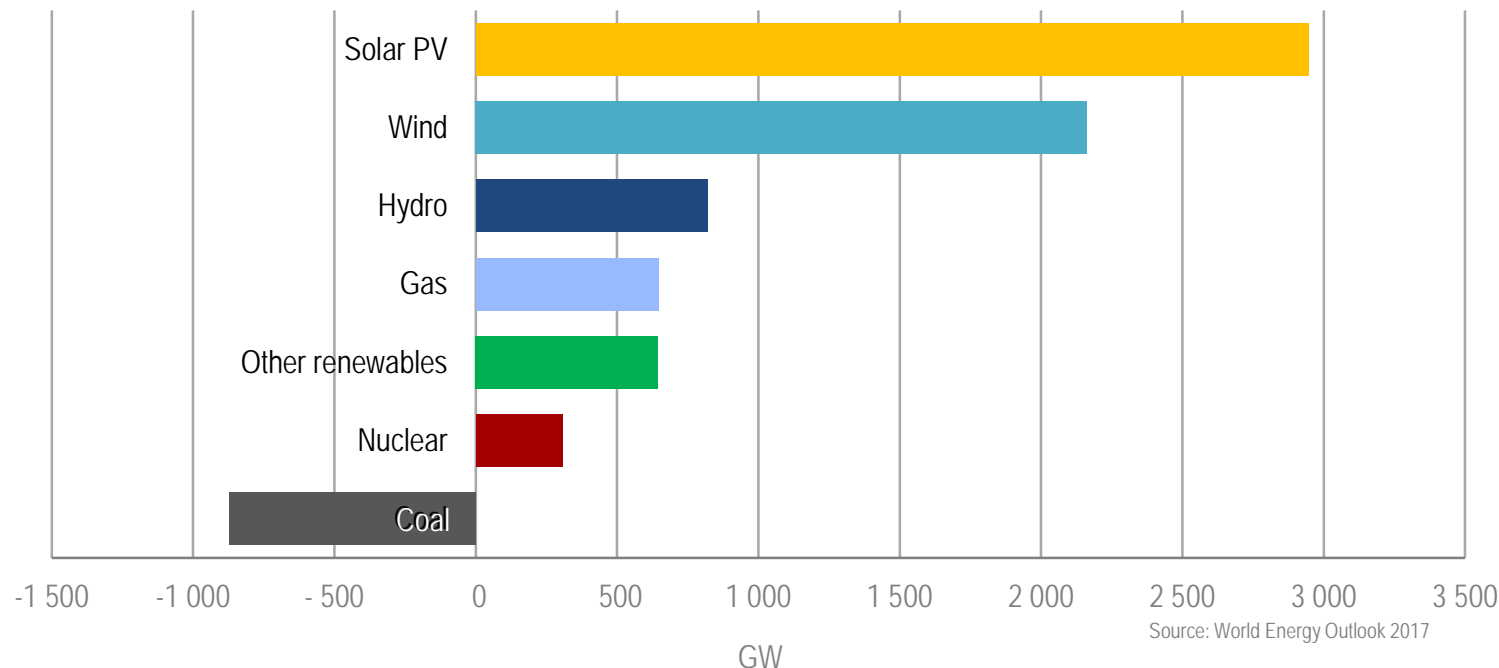
Solar PV enters a new era, becoming the undisputed leader in renewable power capacity growth; PV also accounts for 60% of the upside potential in the accelerated case

PV manufacturing capacity and net annual additions, 2010 – 2022



Renewables dominate capacity additions to meet sustainability goals

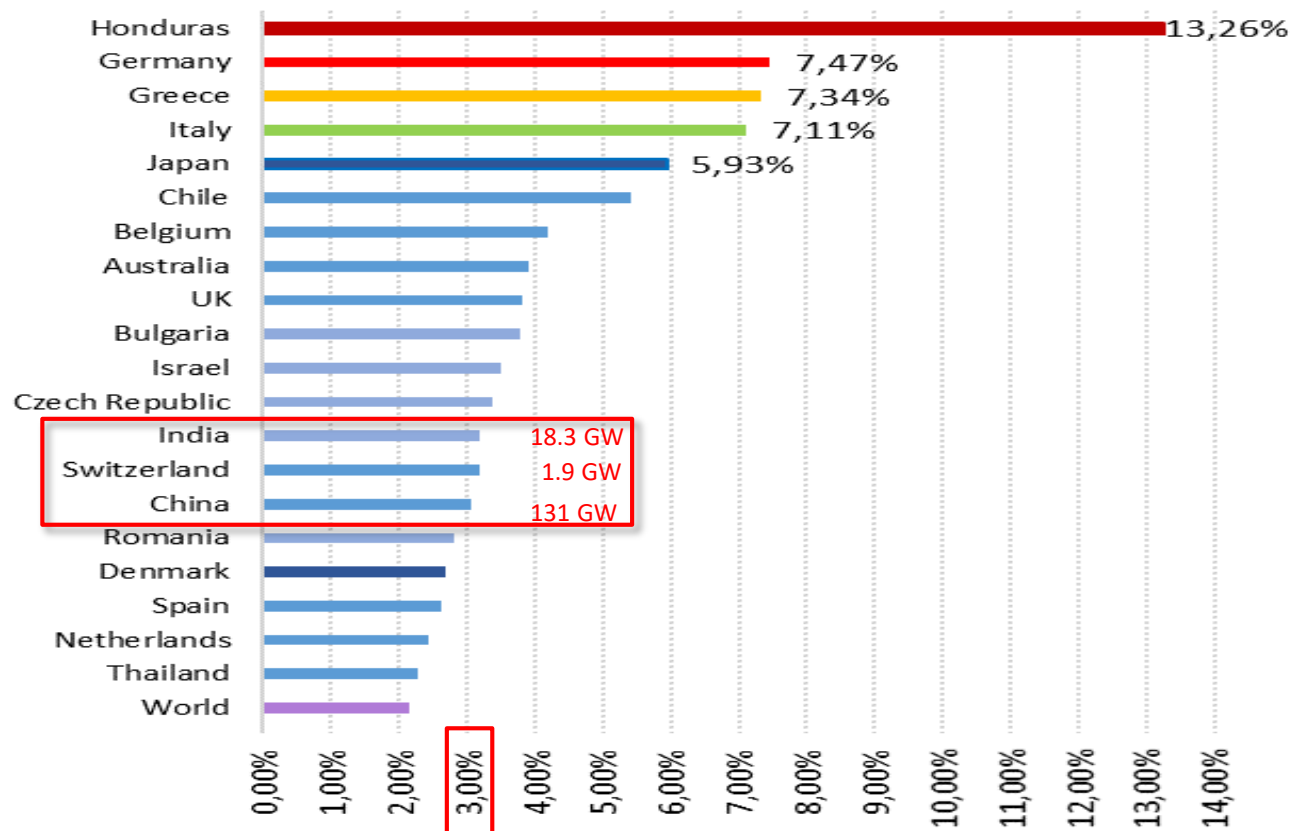
Global net capacity additions 2016 – 2040 in the WEO Sustainable Development Scenario



Renewables account for 63% of total world electricity generation by 2040 in the SDS, with wind and hydro becoming the largest sources of generation. China and India account for over 40% of net renewable additions.

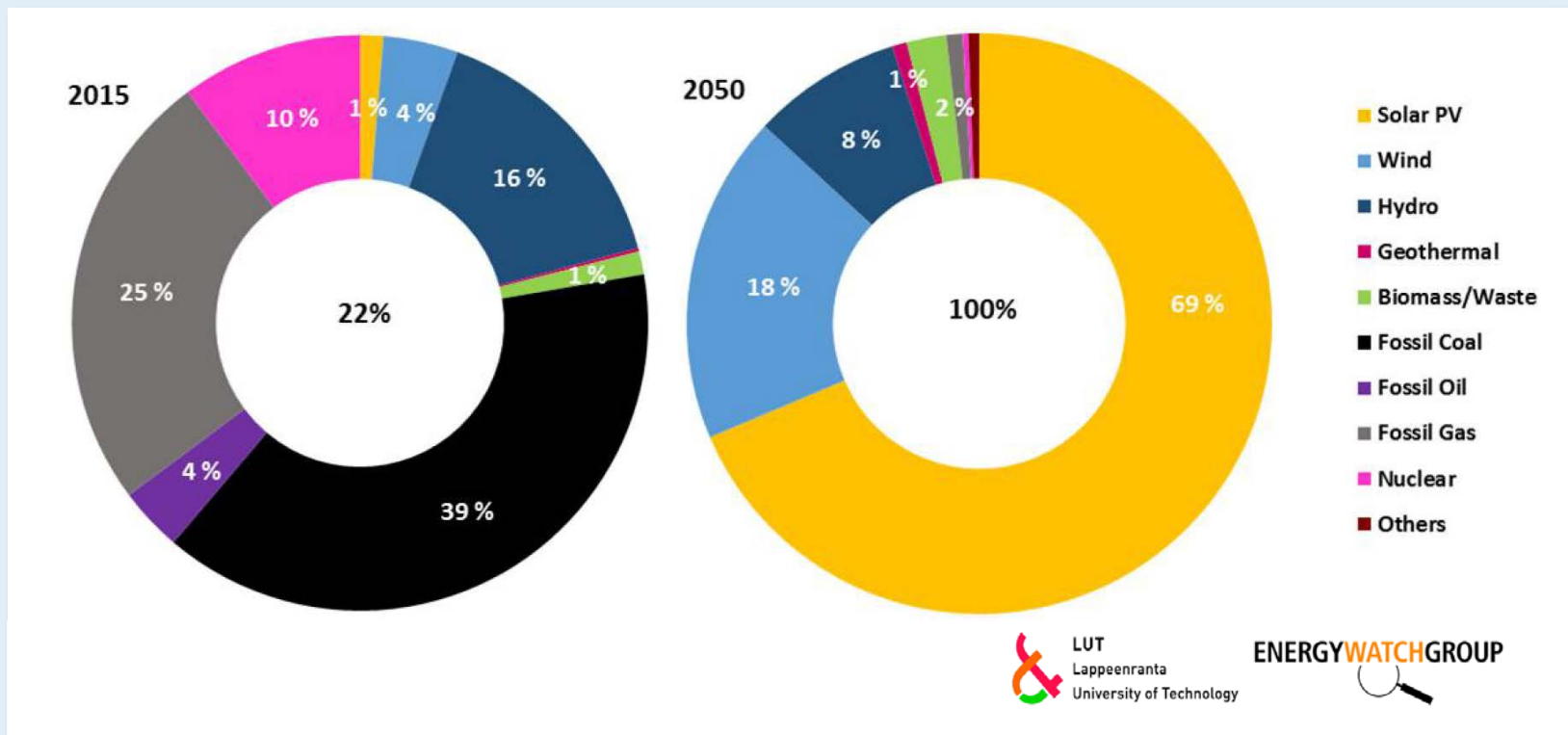


Photovoltaik Anteil heute





Eine Vision: Strom 100% erneuerbar





Herausforderungen für PV als *Mainstream*

- Nachhaltigkeit in allen Dimensionen
- Integration im Energiesystem
- PV – mehr als Strom
- Rahmenbedingungen
- Bereitschaft, Verantwortung zu übernehmen



Herausforderungen der PV: Integration !

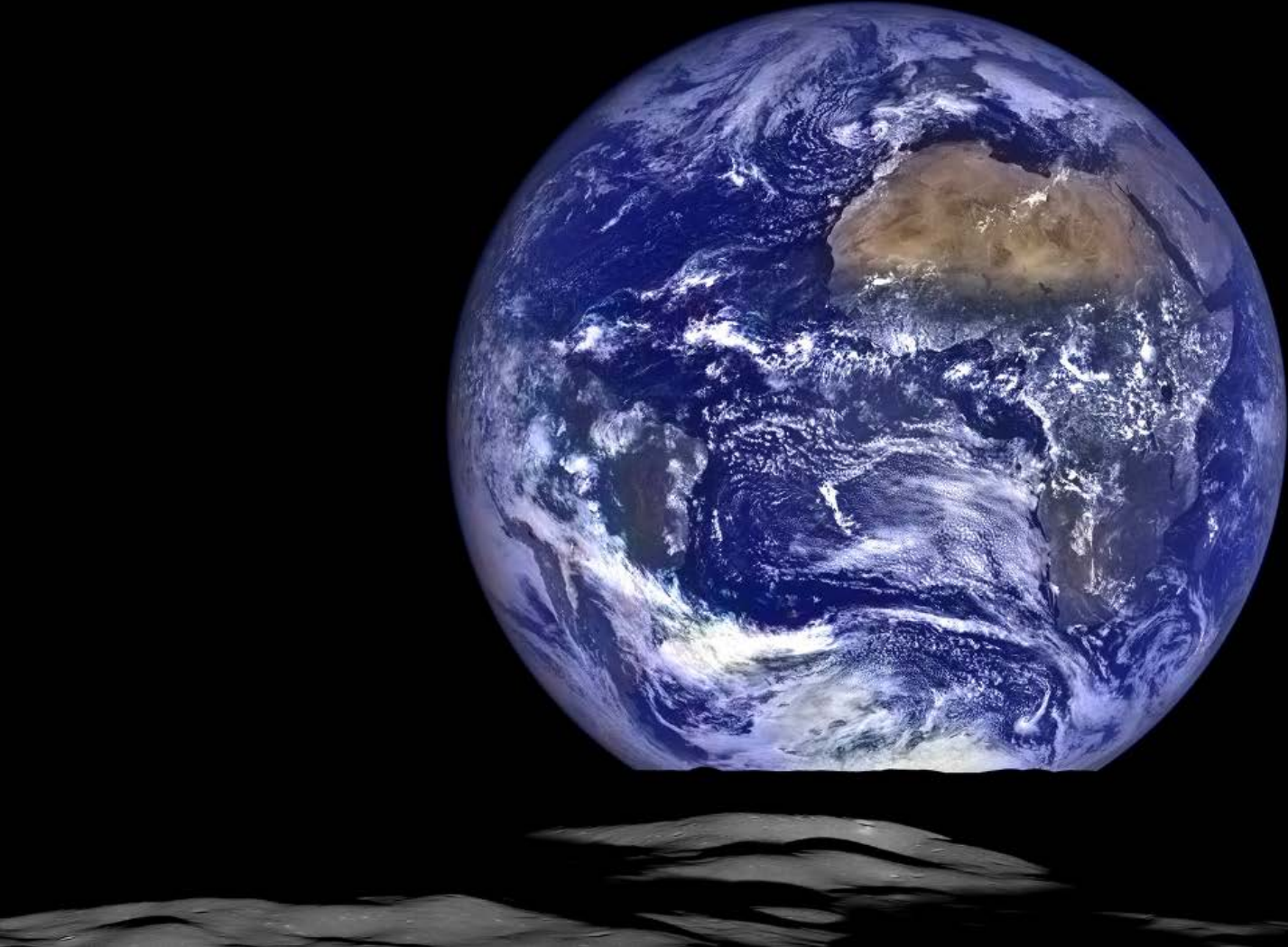
- PV & elektrische Netzintegration
hohe Netzdurchdringung, Netzmanagement, Flexibilität
- PV & Speichertechnologien
Speichertechnologien, P2X, Kurzzeitspeicher, saisonale Speicherung
- PV & Gebäude/Infrastruktur
BIPV, BAPV, PVT, Technologien, Ästhetik, Design, Normen
- PV & Mobilität
Plug-in hybrids, onboard PV, Ladeinfrastruktur, vehicle-to-grid
- PV & Energiesystem
Elektrizität, Wärme, Treibstoffe (solar fuels)
- PV & Energiemarkt
Markt design, Geschäftsmodelle, regulatorische Rahmenbedingungen



Schlussfolgerungen

PV – auf dem Weg zur wichtigsten Stromquelle weltweit?

- Technisch
- Wirtschaftlich
- Politisch
- Gesellschaftlich





Merci / Danke!

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